1951–52.

THE PARLIAMENT OF THE COMMONWEALTH OF AUSTRALIA.

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OF THE

COMMONWEALTH SCIENTIFIC AND INDUSTRIAL RESEARCH ORGANIZATION

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COMMONWEALTH OF AUSTRALIA.

Commonwealth Scientific and Industrial Research Organization.

FOURTH ANNUAL REPORT FOR THE YEAR ENDING 30TH JUNE, 1952.

I. INTRODUCTORY.

1. GENERAL.

The Commonwealth Scientific and Industrial Research Organization was established on 19th May, 1949, when the *Science and Industry Research Act* 1949 was proclaimed. Under that Act the Organization took the place of the existing Council for Scientific and Industrial Research, which in turn had, in 1926, taken the place of the former Institute of Science and Industry.

The powers and functions of the Organization include the initiation and carrying out of research in connexion with, or for the promotion of, primary and secondary industries in the Commonwealth or any Territory of the Commonwealth, or in connexion with any matter referred to the Organization by the Minister; the training of research workers; the making of grants in aid of pure scientific research; the testing and standardization of scientific apparatus and instruments, and the carrying out of scientific investigations connected with standardization; the collection and dissemination of information relating to scientific and technical matters; and acting as a means of liaison with other countries in matters of scientific research.

2. ADVISORY COUNCIL—MEMBERSHIP.

During the past year, Mr. N. K. S. Brodribb resigned from the Advisory Council.

3. ANIMAL GENETICS.

The Animal Genetics Unit was established during the year in co-operation with the University of Sydney. The Unit is located in the Departments of Zoology and Veterinary Physiology and is under the leadership of Dr. J. M. Rendel. In addition to undertaking research, officers of the Unit are carrying out such teaching of undergraduates or supervision of post-graduate research students as may be necessary for the development of higher training in animal genetics within the University.

4. APPOINTMENT OF CHIEF OF DIVISION OF PLANT INDUSTRY.

Dr. O. H. Frankel has been appointed Chief of the Division of Plant Industry in succession to Dr. B. T. Dickson, who retired during the year after more than 23 years' service as Chief of the Division. Prior to this appointment, Dr. Frankel was Director of the Crop Research Division of the New Zealand Department of Scientific and Industrial Research.

5. HONOURS AND AWARDS.

Dr. L. B. Bull, Chief, Division of Animal Health and Production, was awarded the C.B.E. in the New Year's Honours in recognition of the contributions to science made by him and his Division, and his work over a lifetime for the welfare of the wool and livestock industries.

The British Government, on the recommendation of the Royal Commission on Awards to Inventors, made a substantial *ex gratia* monetary award to Dr. E. G. Bowen, Chief of the Division of Radiophysics, for his work in England on the development of radar. This honour he shared with Sir Robert Watson Watt, the original inventor of radar. The American Institute of Navigation recognized the work of Dr. Bowen and his Division by granting him the 1950 Thurlow Award for outstanding contributions to scientific navigation, including the development of Distance Measuring Equipment, Multiple Track Radar Range, and the Microwave Navigational System.

6. DEVELOPMENT OF NORTHERN AUSTRALIA.

The Organization has continued its work in collaboration with State and other authorities in the development of the primary production potential of the northern regions of the continent. Apart from the basic investigations in progress in several Divisions and Sections which are of importance to the north, there are a variety of specific projects bearing directly on problems of northern areas, for example, the pasture work of the Division of Plant Industry and the beef cattle survey of the Division of Animal Health and Production. Special attention is directed, however, to certain aspects of these problems which arose from the activities of the Northern Australia Development Committee.

At the Katherine Research Station, Northern Territory, the rainfall during the 1951-52 "wet" season was the lowest since readings were first taken in 1884. The performance of crops under dry land conditions was severely affected, but useful observations relating to the drought resistance of crop and pasture plants were made. Co-operative investigations with the Western Australian Department of Agriculture on the heavy soils at the Kimberley Research Station near Wyndham, Western Australia, have continued. These soils under irrigation are capable of high initial crop and pasture yields, but fertility falls rapidly. This may be bound up with the physical condition of the soil. Pests and diseases present other serious problems.

The survey unit of the Land Research and Regional Survey Section is now completing the survey of the Ord-Victoria River Region and is making a reconnaissance of the Fitzroy River Valley.

7. EXTERNAL TERRITORIES.

Under the Act, the Organization is charged with responsibility for research of interest to primary and secondary industries not only of the Commonwealth, but also of Australia's external territories. Co-operative investigations with the authorities in the Territory of Papua-New Guinea have been commenced in connexion with tropical beef and dairy cattle breeding. A survey unit has been established as part of the Land Research and Regional Survey Section to undertake a long-term survey of lands in Papua and New Guinea.

8. WOOL PRODUCTION AND TEXTILE RESEARCH.

The major activities associated with the programme of biological research in the field of wool production are reported in Chapter VII. This work is carried out mainly in the Divisions of Animal Health and Production, Biochemistry and General Nutrition, and Plant Industry.

Research on wool textiles is reveiwed in Chapter XV. An extensive programme of work on wool utilization has been developed in the Wool Textile Research Laboratories established in Melbourne, Sydney and Geelong. During the year tests have demonstrated the value of the new L.B.E. sheep branding fluid, which meets a long-standing demand for a practical brand easily removed in scouring. It is now widely used in Australia, and commercial manufacture has commenced both in Australia and overseas. Methods for the reduction of shrinkage and the improvement of wear resistance by fibre treatments with resin and nylon derivatives have now reached the pilot-plant stage.

9. MYXOMATOSIS IN RABBITS.

Following the spectacular spread of the virus disease, myxomatosis, described in the last Annual Report, all mainland States decided to conduct widespread inoculation campaigns commencing in Spring, 1951. The Wildlife Survey Section has continued its studies of the transmission of the disease.

The sequence of seasonal abundance of the more important insect vectors has been worked out and useful data have been obtained on the range and habits of some suspected vectors. Mosquitoes are undoubtedly important in the transmission of the disease, although rabbit ectoparasites are believed to be largely responsible for the spread during the winter months. The problem of immunity has come to the fore in the past season, with the observation that recovered animals were found in some numbers. It is hoped that future co-operative investigations of the Organization and the Australian National University will lead to a determination of the degree to which immunity to the lethal effects of myxomatosis is heritable. Because of the probability of there being a number of immune rabbits in the relic population, emphasis has been given to the importance of other control measures in the attack on these remaining animals.

10. BUILDING PROJECTS.

Although many Divisions still find it necessary to carry on their work under crowded and difficult conditions, some progress has been made in the erection of new buildings. The new laboratory for the Division of Tribophysics in the grounds of the University of Melbourne is approaching completion and should be ready for occupation early in 1953. Several of the main buildings of the Sheep Biology Laboratory at Prospect, New South Wales, are almost ready for occupation and reasonable progress has been made with buildings for the Wool Textile Research Laboratory at Geelong. The new block for the Division of Industrial Chemistry at Fishermen's Bend, Victoria, has also reached an advanced stage.

11. NEW PUBLICATIONS.

The Organization has established a new series of publications dealing in non-technical language with various aspects of the sheep and wool research programme which the Organization and associated institutions have developed since 1946 with funds provided under the *Wool Use Promotion Act* 1945. These publications are intended to present the story of the investigations and the results arising from them and to indicate their application to the problems of the pastoral industry. During the year three publications in this series were issued.

A new periodical, *Rural Research in C.S.I.R.O.*, has been established to provide a summary of more recent agricultural research and to stress its practical significance. It will assist in making the Organization's results in agricultural research speedily available to State Departments of Agriculture for use in extension work and is to be issued at intervals of three to four months.

12. BRITISH COMMONWEALTH SCIENTIFIC CONFERENCE 1952.

The British Commonwealth Scientific Conference, 1952, was held during February and March, commencing in Canberra and continuing in Melbourne. Arrangements for the meeting were made by the Organization. Representatives of the United Kingdom, Canada, Australia, New Zealand, South Africa, Pakistan, Ceylon, Southern Rhodesia, and the Colonies attended and an observer from the United States of America was also present. Progress in the implementation of plans for co-operation in scientific work made at the British Commonwealth Scientific Official Conference in London in 1946 was reviewed and attention was given to future co-operation.

13. OVERSEAS CONFERENCES.

Officers of the Organization attended a number of important scientific conferences during the year. These included the F.A.O. Conference on Land Utilization in Tropical Regions, Ceylon; International Building Research Congress, London; Symposium on "Reactions in the Solid State", Sweden; British Society of Soil Science Meeting, London; Symposium on Copper Metabolism, Baltimore; Conference on Radio Isotope Techniques, Oxford; Twelfth International Congress of Pure and Applied Chemistry and 75th Anniversary Meeting of the American Chemical Society, New York; Fourth Meeting of the International Commission on Whaling, London; General Conference of the International Institute of Refrigeration, London; and Second F.A.O. Meeting on Mechanical Wood Technology, Austria.

14. OVERSEAS VISITORS.

A number of leading scientists from overseas visited Australia in the year under review. Not all came under the auspices of the Organization, but many visited its laboratories, giving much stimulus and help to its officers. Professor D. R. Hartree, F.R.S., Professor of Mathematical Physics at the University of Cambridge, visited Australia at the invitation of the Organization and the Australian National University. He is one of the world's leading authorities on mechanical methods of computing, and during his visit he discussed mathematical computing with officers of the Organization and of the Department of Supply. Professor E. A. Guggenheim, F.R.S., spent the greater part of his three months' stay in Australia with the Division of Industrial Chemistry in Melbourne, but also visited other Divisions and other capital cities. He is Professor of Chemistry at Reading University, and is a well-known leader in the field of statistical thermodynamics. Professor R. E. Grim, Research Professor of Geology, University of Illinois, paid a short visit to Australia in order to gain a better appreciation of the country's clay resources and ceramics industry. In addition to holding discussions with the Divisions of Building Research, Industrial Chemistry, and Soils, he conferred with leaders of the heavy clay industry throughout Australia.

During the course of its round-the-world voyage, the Danish expedition on the Royal Danish frigate *Galathea* spent some time in Australian waters. During their stay in Sydney, scientists in the expedition visited the Division of Fisheries laboratory at Cronulla.

15. TECHNICAL ASSISTANCE TO SOUTH-EAST ASIA.

The Organization has continued to assist in the operation of the Colombo Plan for providing technical assistance to South-East Asia. An increasing number of research workers from the various South-East Asian countries has been accommodated in the various Divisions and Sections in order to gain laboratory and field experience. A senior officer of the Organization visited India, Pakistan, and Ceylon to advise on the supply of technical equipment to those three countries, and another senior officer visited Ceylon as a consultant for the brick and tile industry.

16. STUDENTSHIPS AND OVERSEAS VISITS.

During the year under review, nineteen officers of the Organization were sent overseas for some months to collect information on new developments in scientific research and to acquire general experience and training in new techniques.

Six studentships were awarded to recent graduates for training overseas in fields which would enable them to fill specific posts in the Organization on completion of their training. One studentship was also awarded from Science and Industry Endowment Fund moneys. In addition, seven studentships and one traineeship were awarded for post-graduate work in Australian universities. At the close of the year 31 holders of studentships and traineeships awarded in previous years were receiving training in the United Kingdom, and five in the United States of America.

17. RESEARCH ASSOCIATIONS.

The Organization has continued to support the Australian Leather Research Association on a basis similar to that on which research associations operate in Great Britain under the aegis of the Department of Scientific and Industrial Research. During the year the Bread Research Institute of Australia has also been recognized as a research association, and financial support for it is being provided.

It is considered that great benefits can result from closer co-operation in research between industry and the Organization. Opportunities for collaboration are welcomed and the Executive will be glad to discuss possibilities for extensions of this scheme to other industries.

18. COLLABORATION WITH UNIVERSITIES.

The establishment of research units within the universities is of great importance as it enables the Organization's officers to enjoy the stimulus and help of authorities in different fields of science. The Organization's work in the universities is mentioned in various places in the main body of this report.

Arrangements for collaborative work with universities are of three principal types. In some cases the Organization has established its own units in university buildings or has erected its own buildings on university property; in other cases, sections have been established to work in existing university laboratories with the Professor acting as Officer-in-charge. It has also been found desirable in some cases, where the universities themselves can undertake complete responsibility for specific research projects, to provide funds to enable research workers to be employed by the universities.

The number of research workers involved in arrangements of these three types is now quite large, and the Organization gratefully acknowledges its debt to the universities, without whose co-operation many important research projects could not have been undertaken.

19. SCIENCE AND INDUSTRY ENDOWMENT FUND.

During the year members of the Executive, as Trustees of the Science and Industry Endowment Fund, made grants to assist research workers as follows:—Mr. B. Shipway, for work on the freshwater crayfish of south-western Australia; Mr. A. Robertson, for ornithological investigations; Mr. E. J. McBarron, for the publication of a botanical paper; Mr. Tarlton Rayment, for taxonomic work on bees; Professor O. W. Tiegs, in connexion with entomological field work; Dr. J. Pearson, for work on comparative anatomy and embryology of marsupials; Professor G. E. Nicholls, for studies of Tasmanian freshwater fauna; Dr. E. B. Brown, for the development of a new recording system for moving coil electric gauges; Miss I. McLennan, for work on Australian marine algae; Dr. B. Breyer, for polarographic work; Dr. T. G. Vallance, for petrological research; Professor H. Waring, for marsupial and allied investigations; and Dr. E. J. Reye, for studies of Ceratopogonidae (sand flies).

In addition, a studentship for overseas training was awarded to Dr. June East to study animal physiology at the National Institute of Medical Research, England.

20. FINANCE.

Chapter XXXV. gives details of expenditure during 1951-52 by the Organization totalling £3,880,098. This amount includes a total of £866,735 derived other than direct from the Commonwealth Treasury, including £292,046 expended from the Wool Industry Fund and £420,423 expended on wool production and wool textile research from funds derived from the Wool Research Trust Account established under the provisions of the *Wool Use Promotion Act* 1945. Certain other expenditure involved in erection costs of buildings was also incurred on behalf of the Organization.

The Organization is particularly gratified by the way in which outside bodies continue to support it, and by the marked interest evinced by certain sections of industry which have provided donations for co-operative research. Among the many contributions received, reference may be made to those of the Commonwealth Bank, Australian Wool Board, Australian Meat Board, Australian Dairy Produce Board, Australian Wine Board, and Australian Egg Board, the Queensland Meat Industry Board, the New South Wales Department of Agriculture and New South Wales Water Conservation and Irrigation Commission, the Metropolitan Meat Industry Commissioners of New South Wales, the Victorian Railways, the George Aitken Pastoral Research Trust, Burdekin Bequest, Ian McMaster Bequest, and Alexander Fraser Memorial Fund, the Dried Fruits Control Board, the Australian Dried Fruits Association and the dried fruits industry, the National Gas Association, the Australian Institute of Mining and Metallurgy, the Australian Cement Manufacturers' Association, the wool textile industry, the timber industry, and the pulp and paper industry.

A statement has been included of expenditure on contributions made by the Commonwealth to the Commonwealth Agricultural Bureaux, and the establishment and maintenance of the Chair of Aeronautics at the University of Sydney, and on grants to the Standards Association of Australia, the Australian National Research Council, and the National Association of Testing Authorities. The Organization is responsible for the administration of the funds expended in this way.

21. ORGANIZATION.

For the purpose of carrying out its research work the Organization has established a number of Divisions and Sections. The Divisions, of which there are now fifteen, comprise the major establishments, which may be further subdivided into Sections; there are also independent Sections comprising establishments which have not reached a stage of development, so far as the scope and magnitude of their operations are concerned, to justify their designation as Divisions.

In the present Report an attempt has been made to group the material according to its subject matter rather than according to the Division or Section concerned. Additional chapters and appropriate cross references have been inserted, however, to permit the work of any particular Division to be reviewed as a whole.

As the Organization's investigations extend on a Commonwealth-wide basis and as many of the investigations which are being conducted—particularly those concerned with problems affecting the agricultural and pastoral industries—necessitate experimental work in the field, a number of branch laboratories and field stations have been established in various parts of Australia.

The Head Office of the Organization is in Melbourne and associated with it are the Organization's Central Library, Agricultural Research Liaison Section, and Central Experimental Workshops.

The Divisions which have been established (in order of their formation) are as follows:—

Plant Industry, with head-quarters and main laboratories at Canberra and field stations and experiment farms at Canberra, Australian Capital Territory, Lawes and Stanthorpe, Queensland, Trangie, New South Wales, and Kojonup, Western Australia.

Entomology, with head-quarters and main laboratories at Canberra and field stations at Trangie, New South Wales, and Rockhampton, Queensland.

Animal Health and Production, with head-quarters in Melbourne and main laboratories in Melbourne and Sydney, a branch laboratory at Yeerongpilly, Queensland, and field stations at Badgery's Creek, Armidale, and Barooga, New South Wales, Cunnamulla, Queensland, and Werribee, Tooradin, and Cobram, Victoria.

Biochemistry and General Nutrition, with head-quarters at Adelaide and field stations at O'Halloran Hill, Robe, and Brecon, South Australia.

Soils, with head-quarters and laboratories at Adelaide.

Forest Products, Melbourne.

Food Preservation and Transport, with head-quarters and main laboratories at Sydney, branch laboratories in Brisbane, and minor laboratories at Gosford, New South Wales.

Fisheries, with head-quarters and main laboratories at Cronulla, New South Wales, laboratories in Perth and Melbourne, and field stations at Brisbane, Hobart, and Thursday Island.

Metrology, Physics, and Electrotechnology, comprising together the National Standards Laboratory Sydney.

Radiophysics, Sydney.

Industrial Chemistry, with head-quarters and main laboratories in Melbourne and branch laboratories in Sydney, Adelaide, and Perth.

Tribophysics, Melbourne.

Building Research, Melbourne.

The following are the Sections:—

Commonwealth Research Station (Murray Irrigation Areas), Merbein, Victoria.

Irrigation Research Station (Murrumbidgee Irrigation Areas), Griffith, New South Wales.

Radio Research Board, with head-quarters in Sydney and branch laboratories in Brisbane and Canberra.

Plant Fibre, Melbourne.

Ore-dressing Investigations, Melbourne, and Kalgoorlie, Western Australia.

Mineragraphic Investigations, Melbourne.

Oenological Research, Adelaide.

Mathematical Statistics, Adelaide.

Dairy Research, Melbourne.

Atomic Physics, Melbourne.

Meteorological Physics, Melbourne.

Tracer Elements Investigations, Melbourne.

Coal Research, Sydney.

Physical Metallurgy, Melbourne.

Wildlife Survey, with head-quarters in Canberra and field stations at Perth and Albury, New South Wales.

Mathematical Instruments, Sydney.

Wool Textile Research Laboratories, with head-quarters in Melbourne and additional units in Sydney, and Geelong, Victoria.

Land Research and Regional Survey, with head-quarters in Canberra and field stations at Ayr, Queensland, Katherine, Northern Territory, and Ivanhoe (Kimberley), Western Australia.

Animal Genetics Unit, Sydney.

In addition, Regional Centres (co-operative research units staffed with officers from the appropriate specialist Divisions to attack the problems of a particular district) have been established as follows:—

Regional Pastoral Laboratory, Deniliquin, New South Wales, with its associated Falkiner Memorial Field Station.

Regional Pastoral Laboratory, Armidale, New South Wales, with its associated field station, "Chiswick".

Tasmanian Regional Laboratory, Hobart.

Western Australian Regional Laboratory, Perth.

Plant and Soils Laboratory, Brisbane.

II. SOILS.

1. GENERAL.

The Division of Soils is concerned with research into the classification, properties, and problems of Australian soils of both an applied and fundamental nature. The Division is the central and main body engaged in soil research in Australia taking part either actively or consultatively in most investigations in this field. The primary objectives are—

(i) The systematic mapping of the soils of Australia in broad categories as an evaluation of national soil resources and as a comparative survey relating pedologically the soil groups of this and other countries.

(ii) The classification and mapping in varying degrees of detail of the soils of specific areas in regions marked for future or more intensive settlement or in which problems of production have arisen; this is a service of immediate value to the farmer and to State advisory and administrative bodies.

(iii) Applied research into problems concerning soil fertility or other chemical or physical factors affecting productivity.

(iv) Fundamental research on the pedology, chemistry, physics, and microbiology of Australian soils. This is an increasingly important activity on which depends progress of applied research in the Division as well as investigations of other Divisions of the Organization and agricultural authorities.

The Division comprises four sections—pedology and soil survey, soil chemistry, soil physics, and soil microbiology. The work described in this chapter is decentralized at five regional centres, namely, Brisbane, Canberra, Deniliquin, Perth, and Hobart, as well as at head-quarters in Adelaide. At Brisbane, Perth, and Hobart, branch laboratories are already in existence and it is proposed to add a large unit at Canberra.

During the past 25 years the Division has accumulated much basic knowledge of soil characteristics and developed a system of land classification accepted by the irrigation and land settlement authorities in the several States. These authorities look to the Division for guidance as to the most effective use of land, which may be provided by reference to other regions having related soil characteristics, where the agricultural or pastoral history may extend over many years providing data on the relative success of various uses and response to varied cultural practice. The Commonwealth and State authorities concerned with building research and mass construction have been closely associated with the soil mechanics work of the Division in relation to stability of foundations; the major soils of Melbourne and Adelaide have been classified, mapped, and characterized.

The Division has co-operated continuously with the Waite Agricultural Research Institute, University of Adelaide, where the main head-quarters laboratories are located, and has kept in touch with State and Commonwealth bodies interested in the research programme. Some State organizations are now appointing specific soils officers and co-operative work has been done with three States. It is hoped that this policy will be extended to all States in the next few years to share the routine surveying involved in opening up new lands or intensifying settlement in older districts.

Six officers have been overseas working in British laboratories or conferring with research workers in Europe and America. A senior officer of the Division was seconded to F.A.O., in Rome, for a period to compile a monograph on Soil Classification. The Division was represented at the meeting of the International Union of Crystallography at Stockholm in 1951, and the opportunity was taken to send officers working overseas as observers to conferences such as the Isotopes Conference in Oxford and meetings of the British Soil Science Society and British Mineralogical Society. The Division represents Australia on the Commission on Soil Genesis and Classification set up by the International Society of Soil Science.

Studies of the behaviour of soils under irrigation at the Organization's Research Stations at Merbein, Victoria, and Griffith, New South Wales, are described in Chapter IV., Sections 2 and 3.

2. Soil Survey and Pedology.

The field work has comprised some soil surveys for the classification and mapping of soils for correlation with land use and some for the definition of problems in fertility and production, together with more fundamental pedological investigations. Work was carried on in all States and in north Australia, embracing a large number of separate units. Detailed surveys covered 103,000 acres and broad-scale surveys about 13,100 square miles.

A new soils map for Australia is being compiled and a manual of Australian soils is in press.

(*a*) *Western Australia.*—A detailed soil map of 20,000 acres in the new Many Peaks Extension settlement near Albany has been prepared. The area is considered suitable for closer settlement but additional knowledge of the soils is needed.

A unit of 25,000 acres in the north Stirling district has been surveyed to determine the suitability of the soils for settlement and their liability to saline influences. This area is marginal for development.

The Swan Valley plain near Perth, about 18,000 acres, has been used at a very variable intensity and a number of problems have arisen, particularly in connexion with horticultural plantings. Of this area, 10,000 acres have been studied in detail. The survey is continuing. There are questions on soil fertility to be resolved as well as problems connected with the intermittent waterlogging of the soils that has been an important factor in the decline of existing vineyards and the lack of success of newly planted areas. The significance of the attack of eelworms on root systems as compared with other defects connected with soils is receiving consideration. A considerable variety of soil types has been defined, bearing on land use, which appears less intensive than is warranted under such favorable geographic and climatic conditions.

Minor work on the coastal plain south of Perth is related to the study being made of the effect of saline irrigation water on the soils along the lower Murray River near Pinjarra.

(*b*) *South Australia.*—The development of the low fertility lands occurring very extensively over the Upper South-East of South Australia has directed surveys to the Keith district as a first step in the mapping and evaluation of this region. Building on to the early survey of 1933 south of Keith, the mapping has now covered an additional 600 square miles in the County of Buckingham. It extends east to the Victorian border and includes a large area being privately developed and subdivided for settlement by the A.M.P. Society. Although early reports indicated that successful pasture establishment was practicable using methods of fertilization discovered by officers of the Division of Biochemistry and Nutrition, the survey revealed the need for discrimination in soils for early development and a cautious approach to large areas with soils that have difficult profile features and potentially more salinity. Wind erosion is also a possibility on some formations. The soil map and report is complete covering the soil types, soil problems, and related features of agricultural usage.

The detailed survey of the first unit of 20,000 acres of the Barossa district has been completed and that of a second adjacent area begun. There is a complex formation of soils and many local problems in land use and association of soil types with horticultural crops. The district is one of the old farming areas in South Australia and deficiencies in old orchards and vineyards and difficulties of re-establishment following decline through age of trees and vines are now manifest. The district could be profitably reconstituted for better land use in parts, and the present survey, by relating soil types to crop problems, is preparing the data for sound advice as the occasion arises. Erosion dangers and the present state of erosion are being studied by a conservation officer of the South Australian Department of Agriculture attached to the field party.

Further surveys have proceeded in the Murray valley covering in detail an extension of 2,000 acres on the south-west side of the existing irrigation settlement at Loxton and in reconnaissance 9,000 acres at Murtho near Renmark. It is desired to add a further portion to the present Loxton area and the survey defined the more usable portion which was mainly second-class land. The design of Loxton has always followed closely the soil pattern and the Division has been responsible for defining this pattern and appropriate crop usage. The Murtho area is a new unit commanded by a high pumping lift but has been shown to have a reasonable area of up to 5,000 acres of satisfactory soil types which could be specifically placed only by detailed survey.

An area of 10,000 acres on Lake Albert near the Murray mouth was mapped for the State Government following the acquisition of the Campbell Park Estate which it was hoped to subdivide into dairy farms. The soil map shows the better soil areas, those more suitable for small-scale irrigation from the lake, and those of an inferior type. The material is with the State developmental authority for subdivisional design and development.

Preliminary examinations are being made by spot surveys in the Adelaide hills district as a beginning of a more comprehensive soil map. The foothills and plains area is also being studied as an extension of the investigation of soils and housing in Adelaide suburbs (Section 5 (*f*)).

Following the mapping of 250,000 acres on Kangaroo Island by the Division for the State Land Development Executive, officers of the Executive are continuing the soil and land-use survey, aided by advice from the Division, and have already satisfactorily mapped a further unit.

(*c*) *Victoria.*—A small amount of broad-scale mapping was done at Rochester and liaison was maintained with State work.

(*d*) *Tasmania.*—Over the past six years field work has proceeded over the Launceston Basin covering about 750 square miles mainly south and west of Launceston. This year the surveys were nearly completed with detailed examination of two small units aggregating 6,000 acres near Campbelltown and Western Junction and broad-scale mapping of 200 square miles east of the South Esk river. It is a pedologically interesting area and with the knowledge of the soils now available its potential for more intensive agriculture should be realized. Some of the detail work has been for the Department of Agriculture and the Land Settlement Authority.

Last year an area of 63,000 acres on the Foo Choo Flats on the east coast of Flinders Island were surveyed and this has now been extended to cover 300 square miles, about half the island, on a broad scale of mapping. Reconnaissance traverses have also been made to gain a broad general picture of the soils of the island.

Progress has been made with the project of mapping the soils of Tasmania in broad groups. A commencement was made near Hobart using military index sheets as geographical units; two of these—Brighton and Sorell—are complete and a third is in progress. The aggregate area done during the year was 750 square miles. The mapping system used was based on parent material and topography which dominate the soil-forming factors in southern Tasmania. Aerial photographs have been used for this, as in all surveys, and interpretation of them affords the easiest and quickest method of mapping away from ground traverses.

(*e*) *New South Wales and Australian Capital Territory.*—Reconnaissance survey of the area covered by the military sheets of Canberra and Goulburn on the Southern Tablelands has been completed and detailed mapping of selected small units is proceeding. This is an extension from the large area to the south previously mapped in the same fashion. Some detailed spot surveys for this have also been completed and the full map is ready for draughting.

A moderately detailed survey of the Australian Capital Territory has been continued and half the area completed. Spot surveys in greater detail are being made with particular regard to soil type, land use, and erosion.

At the request of the Irrigation Commission, an area of 600 square miles in the Warren district has been examined in moderate detail for its soil pattern and suitability for irrigation. Two areas at Narromine and Nyngan were reported on previously. This brings the position to a choice between the three areas for development with the limited water supply available. Co-operation by officers in the Irrigation Commission and the State Department of Agriculture was welcomed.

(*f*) *Queensland.*—After completion of the field work in the lower Burdekin valley in 1950 the main soil associations in this area have been defined. A provisional soil and land-use report has been prepared giving a summary in tabular form of the classification of the soils, their relation to topography and vegetation, and their probable irrigation and fertility characteristics, together with a soil map. Pedological problems have arisen in connexion with this survey, notably the morphology and pedogenesis of solonized and solodic soils, large areas of which are present in the valley. Rainwater analyses have revealed that cyclic salt accession may be an important factor in salinization.

A broad-scale reconnaissance survey of approximately 10,000 square miles was carried out in north-west Queensland in the Leichhardt and Flinders river systems north of Cloncurry for the purpose of defining the major soil groups from the viewpoint of soil improvement. It was concluded that the contribution of the Division to the general problem of increasing carrying capacity for cattle would be small compared with the need for improved husbandry (e.g., fodder conservation and the use of new fodder species). However, minor improvements could be effected through local irrigation schemes and clay-pan reclamation, although many heavy saline clays were encountered with very low irrigation potentiality.

A study of the classification and properties of the black earth soils, which constitute an important soil group in sub-coastal Queensland, has begun with the preliminary reconnaissance surveys of the Darling Downs, in which region are some of the soils in Queensland most suitable for arable farming and dairying. Two preliminary surveys have been completed, one embracing the upland basaltic areas in the Mount Gowrie area behind Toowoomba, the other covering the alluvial plains further west in the parish of East Prairie. The soils encountered were mainly heavy black clays and clay loams, belonging to the black earths, showing marked micro-relief in the virgin state.

A detailed survey of the Organization's Experimental Farm at Strathpine, near Brisbane, was undertaken at the request of the Division of Plant Industry. This area is situated on deep red earth residual soils, the truncated remnants of an old laterite which is revealed by mottled and pallid zones at considerable depth.

(*g*) *North Australia.*—Three small areas have been studied and mapped in the Katherine district, Northern Territory, to provide basic soil data for the Land Research Section's experimental programme and the pilot farm now being opened by the Department of Territories. The Katherine Experiment Farm of 100 acres was surveyed in very close detail as it is intensively used for experiment. The surveys should make the experimental programme easier and more widely applicable and, as two of the areas are typical of the Tipperary Land System, considered the best agriculturally in that region, the maps should prove significant indicators of some soil formations.

An officer has been seconded for three years as pedologist to the North Australia Survey Unit of the Land Research and Regional Survey Section. The pedological work of this survey is correlated by the Division of Soils.

3. Soil Chemistry.

(*a*) *Ion Exchange and pH Studies.*—Work which has been in progress on the nature of spurious potentials occurring in electrode systems, such as that used for pH measurements in soils, has indicated that more accurate and more sensitive instruments are necessary before a satisfactory assessment of the hydrogen ion status in suspensions of these cation-dominant soils can be made. A suitable potentiometer and amplifier are now being assembled. In contradistinction to the ideas of many workers, it has been found that the potential at the potassium chloride bridge of the reference electrode may reach sizable proportions if the equilibrium liquid from between the colloid particles and not the colloidal suspension itself is in contact with the potassium chloride solution of the junction.

A simplified technique has been successfully applied to the determinations of total exchange capacity in small samples of soils. The method involves two centrifugings, at room temperature, of the soil or colloid with normal ammonium acetate (pH 7.0), decanting each time, and making a microkjeldahl determination upon the soil and the small amount of ammonium acetate remaining with it. The ammonium content of the residual solution, calculated by weight difference, is deducted from the total amount of ammonium found.

(*b*) *Terra Rossa and Rendzina Soils.*—Progress has been made in the chemical study of the interrelationships of terra rossa and rendzina soils. This project seeks to account for the formation of these morphologically different soils on apparently similar parent materials and under the same climatic conditions. The work this year has been concentrated on the inorganic fraction with particular emphasis on a study of the free ferric oxide. In seeking to elucidate the nature of this free ferric oxide in the clay fraction, a joint investigation has been carried out with the Soil Physics Section and co-operation has been obtained from the Mines Department of South Australia and the Division of Building Research. X-ray diffraction patterns (obtained both by photographic and Geiger counter techniques), differential thermal analyses, and determinations of the magnetic properties have revealed the presence of haematite, goethite, and a ferromagnetic mineral in the clays from these soils. Not all clays contained haematite and goethite, but all those examined contained the ferromagnetic component. The isolation and identification of this mineral is proceeding.

(*c*) *Availability of Copper and Manganese.*—The study of the soil chemistry of micro-nutrient metals has been continued by means of pot experiments and in the laboratory. The retention of added metals in the surface layer of soils was demonstrated for copper and manganese by analysing successive layers of the soil in the pots after harvesting a crop of oats which had been treated with solutions of these metals. It was found, in some cases, that this distribution of the metals in ths soil was less favorable to uptake of copper and manganese by oats than was a uniform distribution throughout the pot. With some soils, the application of copper at a rate equivalent to 20-100 lb. $CuSO_4.5H_2O$/acre brought about a lowering of the manganese uptake of oats. However, very heavy applications of copper sulphate (equivalent to 500 lb./acre) resulted in increased uptake of manganese from two of these soils.

In the laboratory a study has been commenced of some of the extractants which have been used for the fractionation of soil manganese with a view to developing better methods for the identification of manganese compounds in soils.

(*d*) *Spectrochemical Investigations.*—Further work has been carried out on the quantitative spectrochemical determination of various elements in soils and plant ash. In continuation of the work on the use of potassium sulphate as a spectrographic buffer in the determination of manganese in plant material, samples of three plant species were examined, but it was found that the buffering effect was not sufficient to overcome the effects of the big differences in composition of the ash of the different species. A factorial experiment is now in progress, seeking to determine precisely the influence of the three major components of the ash (potassium, calcium, and silicon) on emission by minor components. The Lundegardh flame technique is being used for the determination of sodium, potassium, calcium, and magnesium in conjunction with the D.C. arc analyses for the minor components.

Attention has been given to the frequency distribution and other statistical properties of the error which occurs in the spectrographic analysis of soil and plant ash when D.C. arc excitation is used. The results will be of great value in the dissection of total error into the component errors in spectrochemical techniques.

Some elements of agricultural interest, such as cobalt, are present in very low concentrations in plant material and can seldom be determined directly in the plant ash. Preliminary chemical concentration is necessary and a modification of a method worked out at the Macaulay Institute has been successfully applied to the determination of cobalt in concentrations as low as 0.01 p.p.m. in dry matter.

Previous work with the Lundegardh flame technique, for the determination of exchangeable cations in soils, has shown that the analytical result for any one element may be influenced by the level of concentration of another cation present. A study is being made of the influence of each cation (sodium, potassium, magnesium, and calcium) on emission by the other three in the ranges of concentration encountered in soil analysis.

During the year two officers of other Divisions and one visitor from New Zealand have taken advantage of the facilities and experience available in this Division to study spectrochemical techniques. The facilities have also been made available to various outside organizations.

(*e*) *Special Analytical Methods.*—Routine chemical examination of type samples of soils collected by the Soil Survey Section continues to be an important phase of the work carried out in the laboratories. Now that some of this work is being done in the Regional Laboratories, more time can be devoted to determinations specifically directed to some of the special needs of the different surveys. The officer in charge of this phase of the work is at present abroad investigating methods found useful in connexion with the chemical description of soil survey samples in other parts of the world.

(*f*) *New Physico-Chemical Laboratory.*—A new laboratory for physico-chemical work on soils is being equipped so that it can be maintained at a controlled temperature of 25° C. This laboratory will facilitate the above work and will enable active work to start on a new project investigating the electrokinetic properties of clay particles and the functions of salts in soil solutions.

(*g*) *Brisbane Regional Laboratory Investigations.*—Work on the soil chemistry of elements needed for plant nutrition has been initiated. One project in progress concerns the equilibrium levels of mineral-nitrogen in virgin black clays on the Darling Downs. Techniques of determination of nitrate and ammonia nitrogen in soil extracts have closely followed those developed in

Adelaide and it has been found possible to handle conveniently and rapidly replicated samples from three regular sampling sites at distances of over 100 miles from the laboratory. Preliminary results show that the mineral nitrogen levels in these soils are very low, although nitrification of added ammonia nitrogen proceeds rapidly under incubation conditions.

Following observations by workers of the Division of Plant Industry on the possible unavailability of zinc to certain pasture species in black soils on the Darling Downs, an attempt is being made to fractionate the various forms of this element. Preliminary work has centred on the provision of a reliable method for determining total zinc in soil and a tentative polarographic procedure has been devised which eliminates interference from copper and cobalt. Further work is continuing in order to throw more light on the mechanism of this elimination, which involves the relative stability towards dilute acid of the complexes of copper, cobalt, and zinc with di-β-naphthylthiocarbazone.

Analyses performed on Burdekin river water show a low boron and total salt content; there is evidence that soluble silica, as sodium silicate, is present, which may indicate some degradation in saline or solonized soils in the valley.

4. Soil Microbiology.

(*a*) *Trace Elements and Micro-organisms.*—Little is known of the source of trace metal ions in soils, so a study is being made of the availability to the fungus *Aspergillus niger* of the metals iron, zinc, copper, manganese, and molybdenum from finely ground rocks and unweathered minerals such as are often found in the parent material of Australian soils. Some rocks, e.g. basalt, contain appreciable amounts of all trace elements in an available form. Certain ferromagnesian silicate minerals such as hornblende and biotite mica are good sources of most trace metals; some commonly occurring metal oxides and sulphides also contain small amounts of several other trace elements. Most felspars are deficient in all trace metals except iron.

The bioassay of trace metals by observing the extent and type of growth of *A. niger* corresponds fairly well to plant requirements for zinc, copper, and molybdenum, but not for iron and manganese. The growing fungus itself produces large amounts of organic acids, and these by-products in turn dissolve out from the rock mineral certain oxides of iron and manganese, making them available as food for the fungus in a way which is normally not done by plants. This interference cannot be avoided by controlled reduction of the acidity under experimental conditions, because if this is done there is also a big change in the deficiency symptoms in the fungus. Accordingly, other micro-organisms have been sought, including bacteria, fungi, and actinomycetes, which would produce less acid and at the same time give distinct deficiency symptoms. The best micro-organism to date has been the fungus *Alternaria* sp. which maintains a pH of 7 and shows marked deficiency symptoms for iron, zinc, copper, and manganese. Several actinomycetes and bacteria produced very little acid, but were unsuitable for bioassaying since they showed deficiency symptoms only for iron and sometimes zinc.

An attempt is being made to develop a bioassay method for boron, using algae grown in plastic or silica containers, and for cobalt using actinomycetes, which need cobalt for the synthesis of vitamin B_{12}.

It is debatable whether soil micro-organisms seriously compete with higher plants for the meagre supply of trace elements in deficient soils. This subject is being explored by comparing the respiration of micro-organisms in deficient soils, before and after the addition of trace elements. Oxygen consumption and carbon dioxide production are being measured over a period of many days in a continuous-reading type of respirometer recently developed in this Section.

(*b*) *Rhizosphere Micro-organisms, Rhizobia, and Subterranean Clover.*—Work has continued in field trials and in glass houses on the influence of rhizosphere micro-organisms on the growth and nodulation of subterranean clover. In the field it has been found that numerous clover plants failed to develop much beyond the seedling stage, and exist throughout the season in a yellow, stunted condition. It is thought that the growth of seedlings is checked by adverse conditions, such as shortage of phosphates, nitrogen, and calcium, by temporary waterlogging, or prolonged frost. When this occurs a number of common micro-organisms, originating from either the seed or the soil, enter into rhizosphere relations with the clover, invade the roots, and set up a systemic infection which appears to interfere with nitrogen fixation.

Further glasshouse work has confirmed the view that different strains of *Rhizobium trifolii* compete with one another for site of nodulation of subterranean clover so that effective strains are sometimes overwhelmed by ineffective strains.

Uninoculated subterranean clover, sown in autumn, in fields containing relatively few naturally occurring rhizobia, nodulated poorly at first, but developed sufficient numbers of effective nodules to give good healthy plants at the end of the growing period.

Cross-inoculation tests performed with rhizobia isolated from native leguminous plants show that most belong to the cowpea group. The indigenous rhizobia present in many of our virgin soils contain *R. trifolii* although clovers have never grown in these areas.

5. Soil Physics and Mechanics.

(*a*) *Damage of Soil by Rain.*—Impact of heavy rain may cause compacting of the surface layers of soil which increases both the run off of water and the rate of erosion. A laboratory study of this effect is in progress. In the field a study is being made of the effect of crop rotation on bulk density of the cultivation zone, using rotation plots of the Waite Institute. It has been found that in a very wet winter the bulk density of soil during the wheat course was greater in a fallow-wheat rotation than in a fallow-wheat-peas-Wimmera ryegrass rotation. At the same time germination was greatly depressed in the fallow-wheat rotation.

(*b*) *Mechanism of Water Movement in Soil.*—Problems relating to the movement of water are common to both agricultural and engineering fields. Work reported last year on the effect of a temperature gradient on water movement has produced striking results and this is being continued with improved apparatus. The circulatory flow that has been observed in closed columns of soil, i.e. movement as water vapour toward the colder end and return as liquid in the opposite direction, requires a much greater rate of flow of water vapour than would be expected in a system at uniform temperature with the same vapour-pressure gradients. Present work is therefore designed to study the effect of a temperature gradient on the diffusion rate of water vapour in soils.

(*c*) *Properties of Soils in Relation to Irrigation Development.*—The characterization of the physical properties of soils from the lower Burdekin valley, Queensland, has been continued at Brisbane. The properties measured are those most concerned with the behaviour of the soils under irrigation culture. Many of the soils are likely to present difficulties in their adaption to this new form of culture, although particular types should prove very suitable. A review of the infiltration work, which was carried out during the soil survey, has been completed and will be published. The infiltration data cover all the more important types defined in the area and give some indication of the behaviour to be expected under irrigation. Rates of water entry are mostly low due to the compact nature of the soils and some improvement would probably follow deep cultivation prior to irrigation.

In connexion with the above work a series of laboratory methods has been devised. An examination of the range of available water has led to the establishment of a method for determination of field capacity by draining soil aggregates at a definite water tension. This indirect determination has been found to agree closely with field results. The influence of soluble salts on the indirect determination of soil wilting point has been examined. The error introduced by salts is usually small and does not appear to be of consequence except for high concentrations. A general examination of wilting point values in relation to texture suggests that these values are related closely to clay content, and indicates that the surface area of the clays determines the amount of water held at wilting point. The clay content may enable an estimate of this value to be made.

(*d*) *Seasonal Changes in Water Content of Soils.*—Fluctuations in the water content of clay soils can greatly affect the stability of roads and houses. The downward movement of rainfall water into soils has been studied, using gypsum-block moisture meters to record the arrival of the wetting front. Gypsum blocks continue to give information on the seasonal changes in soil moisture tension in naturally exposed soils. The amount of seasonally stored water in soil profiles at Adelaide has been calculated from field measurements of water contents and compared with values calculated from meteorological data. Very deep installations of gypsum blocks (to a depth of 15 feet in one soil profile) have been made with a view to measuring soil moisture tension in the whole part of the profile affected by seasonal changes.

The changes of soil moisture tension under a sealed roadway have been measured and the influence of such cover on the soil moisture régime in the Adelaide environment assessed.

(*e*) *Volume Change of Soils caused by Changes in Water Content.*—Records continue to be made of seasonal movements in clay soils resulting from changes in water content. The soil movements have been examined critically in relation to the measured amount of water causing them, and information on the mechanism of swelling and shrinking of the soil profile has been obtained. Soil movement installations have also been put in to depths of up to 15 feet.

In the laboratory, work on the swelling-water content-tension relationship of clay materials is continuing. Using a remoulded clay material, volume changes have been followed over a range of soil moisture tensions greater than that encountered naturally in the field.

(*f*) *Examination of Soils in Relation to Engineering Problems.*—Work has been continued on the soils of the suburban areas around Adelaide. This work has been co-ordinated with geological features in a project undertaken co-operatively with the South Australian Department of Mines. A publication of that Department is being issued, covering the results of this co-operative work on the soils and geology of Adelaide and suburbs. In this the soils are described in detail and in such a way as to enable their recognition in the field. The engineering behaviour of the various soil types is discussed and a map is given showing their general distribution. A similar project is now being undertaken in Melbourne.

(*g*) *Soil Colloid Studies.*—Consideration of the red-brown earth group of soils, especially in the Adelaide area, continues. Further work has given strong evidence of the presence of much amorphous and "semicrystalline" material in samples from certain profiles; the presence of such material seems to be strongly correlated with high swelling properties. Soils which contain little of such material are also better for house building. Results of analyses by thermal methods support the X-ray data in these conclusions. Further work on clay fractions of Queensland red-brown earths has shown them to be mainly halloysite. Several red-brown earth profiles from the Northern Territory, north-western Queensland, and Tasmania, have clay-mineral compositions which do not fit into the general pattern of the red-brown earths of southern Australia or Queensland.

A study of the terra rossa and rendzina soils around Adelaide, and in the south-east of South Australia, was also commenced. So far a study of the 2-micron fraction has not yielded any conclusive reason why these two different soils occur side by side. This is mainly because the colloids of these soils appear to be very poorly crystalline and to contain much amorphous material. Some useful results may be obtained by investigating thoroughly the iron oxides in these soils; in several of which magnetite or maghemite has been identified and partially separated.

Assistance was given to a visiting United States soil chemist in using a Geiger counter X-ray spectrometer for estimating quartz and felspars in the silt fraction of some Australian soils. The results were examined in relation to soil fertility and trace element deficiencies.

III. PLANTS.

1. General.

Investigations of problems related to plants are an important part of the Organization's activity. Work reported in this chapter is by the Division of Plant Industry—Sections 2-21; the Land Research and Regional Survey Section—Sections 22-25; the Division of Biochemistry and General Nutrition—Section 26; and the Section of Mathematical Statistics—Section 27.

Work on the special problems of plant cultivation in irrigation areas is undertaken by the Commonwealth Research Station (Murray Irrigation Areas), Merbein, Victoria and the Irrigation Research Station (Murrumbidgee Irrigation Areas), Griffith, New South Wales, and is reported in Chapter IV.

The Division of Entomology is carrying out work on insect pests of pastures and crops, biological control of weeds, and insect vectors of virus diseases. This is described in Chapter IX.

Division of Plant Industry.—Much of the research of the Division is conducted at regional and field stations in many parts of the Commonwealth, with emphasis upon the problems of the pastoral industry, the fruit industry, and tobacco production. Work is conducted at the head-quarters and main laboratories at Canberra and at the following centres: Institute of Agriculture, Nedlands, Western Australia (pasture studies and plant introduction); Glen Lossie Field Station, Kojonup, Western Australia (pasture studies); Kelmscott Introduction Station, Western Australia (plant introduction); Waite Agricultural Research Institute, Adelaide, South Australia (plant physiology); Regional Laboratory, Hobart, Tasmania (apple investigations); Falkiner Memorial Field Station and

Regional Pastoral Laboratory, Deniliquin, New South Wales (pasture studies); Regional Pastoral Laboratory, Armidale, New South Wales (pasture studies); State Experiment Station, Trangie, New South Wales (pasture studies, with New South Wales Department of Agriculture); Plant and Soils Laboratory, Brisbane, Queensland, and Strathpine Experiment Station (pasture studies, plant introduction, tobacco, and medicinal plant studies); Cooper Laboratory, Lawes, Queensland (pasture and weed studies); Field Station, Stanthorpe, Queensland (rootstock investigations); Ayr, Queensland (tobacco, with Queensland Department of Agriculture); Katherine Experiment Station, Katherine, Northern Territory (plant introduction and tobacco); and Dickson Experiment Station, Australian Capital Territory (which acts as regional field station for the work at Canberra).

In addition, extensive trials are conducted on leased or private properties in districts outside the regional centres, often in conjunction with the State Departments of Agriculture. The regional centres are also the bases from which large-scale ecological surveys of natural vegetation are carried out.

During the year, adverse weather conditions, including a severe drought, affected field experiments and trials of new introductions in many of the regional centres.

At the request of the Australian Agricultural Council the Division organized in October, 1951, an Australian Agrostology Conference, which was attended by officers of State and Commonwealth Departments.

2. Plant Introduction.

The Plant Introduction Section introduces and tests plants of potential economic importance from countries similar climatically to Australia. The Section maintains close relations with State Departments of Agriculture and with the Commonwealth Department of Health which is responsible for plant quarantine.

(*a*) *Introduction and Exchange of Plants and Seeds.*—During the year there was a great increase in the international exchange of plants and seeds, largely as a result of overseas plant exploration. More than 3,000 samples were received from overseas countries including Portugal, India, Israel, Morocco, and Italy. Most of those collected were pasture and forage plants. In addition crop plants, including varieties of cotton, rice, and soybeans, were obtained from tropical and subtropical countries for trials in northern Australia. About 1,700 samples were sent in exchange to 48 countries, including the United States, India, Italy, France, and the Canary Islands. About 1,000 samples were also distributed for trial to other organizations and individuals in Australia, mainly the State Departments of Agriculture and Universities.

(*b*) *Plant Exploration.*—Plant exploration in the Mediterranean region was continued with an expedition to Italy, France, Spain, Portugal, Morocco, Algeria, Tunisia, and Egypt. Many of the introduced plants from which southern Australia has benefited have their centre of origin, and of variation, in the Mediterranean basin. No systematic attempt had previously been made to obtain a fuller range of the existing variation than could be secured by correspondence with scientific and commercial organizations. Chance introductions had played the principal part in the establishment of Mediterranean species in Australia. If it is likely that new and valuable strains of such important pasture species as subterranean clover or phalaris may be discovered in a careful search of this native region, it is equally likely that other species, as yet untried in Australia, may be brought to light. Of the 1,260 species and varieties collected, mostly in the field, many were grasses and clovers hitherto untested in Australia.

Another major collecting effort was made in Africa. The recognition and evaluation of pasture and fodder species suitable for the subtropical and tropical regions of the world has scarcely begun. In Queensland there are vast regions with favorable summer rainfall for which suitable grasses and legumes must be developed, and Africa offers great possibilities of finding such species. The search began in the Sudan and continued through Ethiopia, Kenya, Uganda, Tanganyika, the Belgian Congo, tropical West Africa, the Rhodesias, and South Africa.

The collections made include many strains of Rhodes and buffel grass, as well as a complete range of the varieties of *Panicum, Setaria,* and *Paspalum* that have been developed as pasture plants in Rhodesia and South Africa. The mountainous regions of East Africa are particularly rich in indigenous legumes, and numerous varieties of these have been obtained.

The Cape Province is very similar climatically to parts of Western and South Australia. It has been a prolific source both of useful plants and of weeds. Several weeks were spent in this region, and large collections were made of species and strains of veldt grass (*Ehrharta*). Some of these are rhizomatous forms which may withstand close grazing and thus remove the main handicap to the development of veldt grass as a pasture plant.

(*c*) *Agronomic Trials.*—(i) *South-eastern Australia*—The work in Canberra has been on the more promising pasture, fodder crop, and green manure species. This has involved a study of the reaction of pasture introductions under sward conditions at Canberra, Deniliquin, and Trangie. Seed supplies of promising species have been increased to permit more extensive regional trials in Canberra and in north-western New South Wales.

Drought conditions have helped confirm the value of some varieties established in previous years. These include: *Stipa hyalina,* a tufted perennial grass from Argentina and Uruguay, which has shown its usefulness at Trangie and other centres in the semi-arid parts of New South Wales, and *Phalaris aquatica* which has made good winter growth at Canberra, Deniliquin, and in South Australia. In Mildura *Lathyrus ochrus,* originally obtained from Israel, confirmed its usefulness as a green manure species in vineyards. *L. ochrus* consistently outyielded the control species on all properties with a light sandy soil, and also appeared promising as a soil-conditioning plant for heavier soils on which pastures are to be established.

(ii) *Queensland.*—During the year a new Introduction Station was established at Strathpine, which is more satisfactory for quarantine than the old station at Redland Bay.

Chemical analyses have been completed on 100 grasses and 60 legumes grown in the plant introduction nursery at Redland Bay. Species of *Paspalum* from South America and elsewhere, including some strains of Bahia grass (*Paspalum notatum*), show promise, as they combine high protein content with cold and drought resistance, excellent ground cover, and ability to combine well with legumes. Bahia grass has deep root penetration as well as a dense mat of roots near the surface, which enables it to grow well on shallow soils.

Species of *Desmodium, Stylosanthes,* and *Arachis* were oustanding amongst the legumes tested. Species of *Arachis* and *Indigofera* retained their foliage and recovered well under the drought conditions. Root studies showed that the roots of *Desmodium uncinatum* penetrate deeply and are densely nodulated throughout, while those of *Stylosanthes* are nodulated only in the upper parts. The results from the Redland Bay Station have been confirmed in locality trials at Kuraby, Cecil Plains, and Maryborough, and at Lismore, New South Wales.

Experimental work with vegetable oil and other crop plants at Lawes was completed during the year. Trials with varieties of linseed from India showed that they are superior to those now grown in Queensland. They are early maturing, consistently give high yields of oil and grain, and are agronomically better suited to local conditions. They are, however, susceptible to rust in extreme years. Trials with safflower varieties selected for Queensland conditions have been made. In general these selections are taller, later maturing, and relatively spineless. A strain of *Sorghum* introduced from Brazil has shown promise as a fodder crop. It is a tall plant, rapid in growth, with abundant foliage and succulent stems. Trials with soybeans and sunflower have been continued.

(iii) *Northern Territory.*—At the Katherine Research Station trials continued on soybeans, sunflower, guar, peanuts, and *Phaseolus* and *Hibiscus* species, in addition to trials of new introductions. High yields were obtained from the peanut trials which received a slight supplementary irrigation. Some of the peanut introductions, which appeared to have a better capacity to withstand drought than the control varieties, also gave higher yields both at Katherine and at the Kimberley Research Station, Western Australia. At Kimberley, where disease is a most serious problem in peanut crops, some South American varieties have shown a high degree of resistance.

Varieties of roselle (*Hibiscus sabdariffa*) made good growth in a comparative trial, and samples have been sent to Melbourne for fibre evaluation. Similar samples tested from the previous year's crop produced fibre of fair quality, and it appears that fibres of the *Hibiscus* group can be produced in the Territory.

(iv) *Western Australia.*—The new introduction quarantine station at Kelmscott, near Perth, was fully established during the year. The number of new introductions tested in Western Australia was smaller than usual.

Some species of *Bromus* that appear promising for pastures are being tested under field conditions by the State Department of Agriculture. Species of *Hyparrhenia, Agropyron,* and *Brachiaria* also show promise, but poor seed production presents a problem on which further work is necessary.

At Kojonup trials are being continued of cereal varieties suitable for grazing as well as for grain production. Introduced varieties of barley continue to show superiority over local commercial varieties. Some of the oat introductions, however, have not maintained their earlier promise. Further work has been done with strains of *Lathyrus sativus,* whose grain has been suspected to cause poisoning in stock, if fed for long periods. Sheep were carried for four months in the summer entirely on mature plants of *L. sativus* without loss.

(*d*) *Plant Geography.*—Investigations are in progress on plant distribution, particularly on the influence of environmental factors. These investigations are designed to improve methods of testing new introductions.

The usefulness of floristic methods of comparing plant distribution and environment in different countries is being investigated. Studies of grass distribution appear to be particularly useful for this purpose and an index of grass distribution has been derived which shows a close correlation with climatic and other environmental factors.

Experimental growth-rhythm studies have been made, based on a series of regular defoliations of perennial grass species in rows at Canberra over a period of thirteen months. It proved possible to classify the species concerned into groups according to their growth rhythm, despite the fact that the relatively low rainfall prevented a full expression of their growth potential. The seasonal growth rhythm as ascertained at Canberra closely paralleled the performance of the plants under trial at various centres in south-eastern Australia.

Detailed comparative developmental and phenological studies are being made at Canberra and Kelmscott on a selected group of 350 strains of seventeen species, collected in the Mediterranean region.

A new vegetation map of Australia is being prepared to form part of an Australian Resources Atlas. Draft maps have already been drawn for most of the Northern Territory, South Australia, northern Queensland, and northern Western Australia.

(*e*) *Systematic and Economic Botany.*—An additional 3,014 specimens have been incorporated in the herbarium, bringing the total to 26,182. They include collections from northern Queensland presented by Mr. L. J. Brass, collections presented by the Brisbane Herbarium, collections made in northern Australia by Mr. R. A. Perry, and Western Australian plants collected by Mr. I. Common.

Work on material collected by others has again occupied a considerable amount of time. About 800 plants have been determined for C.S.I.R.O. officers stationed at regional centres and for other government departments.

Work has continued on the Australian Amaranthaceae. This study was undertaken because of the importance of the family in the dry pastoral areas of northern Australia. Copies of the majority of the original descriptions have made it possible to construct provisional keys to the genera *Trichinium, Ptilotus, Gomphrena,* and *Amaranthus.*

A flora of the Australian Capital Territory has almost been completed. Microfilm copies of certain manuscripts by Robert Brown and other early Australian botanists have been distributed.

Th manuscript of a revised edition of *C.S.I.R. Bulletin No.* 156 ("Standardized Plant Names") has been completed, with valuable assistance from botanists of the State Herbaria.

3. PLANT GENETICS.

(*a*) *Genetics of Resistance to Legume Viruses in* Pisum sativum *and* Trifolium subterraneum.—Using the more severe of two legume viruses which are similar in properties to Bean Mosiac II., the reactions of the progenies developed from the cross between Greenfeast (susceptible) and William Massey (resistant) were investigated. The segregations are not clearly defined, and the number of resistant plants obtained is small. It is intended to examine physiological aspects of resistance when isogenic lines of both Greenfeast and William Massey, differing only in resistance and susceptibility, are obtained.

Investigation of a number of varieties of subterranean clover has shown that they can be classified into either mottle-reacting or lethally-necrotic groups. The varieties in the latter group are usually resistant under field conditions. Hybrid progenies between varieties representative of the two groups are being developed.

(*b*) *Interspecific Hybridization in the Genus* Phalaris.—The main species being investigated are *P. tuberosa, P. aquatica, P. arundinacea, P. coerulescens,* and *P. minor.* Two interspecific hybrids have been obtained and these are to be multiplied. The effect of natural selection on the progenies will then be examined in several habitats.

(*c*) *Combination of Virus Resistance, Late Blight Resistance, and Desirable Agronomic Characters in the Potato* (Solanum tuberosum).—Hybrids combining resistance to potato viruses X and Y, and to late blight, and retaining high yield have been developed but their tuber type is poor. Other hybrids possessing good tuber type and resistance to viruses X and Y and leaf-roll have been obtained. By suitable intercrosses it is hoped to produce potato types combining all these desirable features.

A study of the reactions of the resistant hybrids to the different viruses has indicated that resistance is due to the presence of virus-inactivating systems and not to hyposensitivity. Leaf-roll resistance appears to be associated with restriction of virus development in the phloem, a character indicated by severe phloem necrosis following sprout infection by aphids.

(*d*) *Combination of Spotted-wilt Resistance, Fusarium-wilt Resistance, Eelworm Resistance, and Desirable Agronomic Characters in the Tomato* (Lycopersicon esculentum).—Investigation of spotted-wilt resistance in *Lycopersicon* species indicated that resistance may depend upon a virus-inactivating mechanism. At temperatures above 90°F. inhibition of the virus by resistant types is accelerated. Since Rey de los Tempranos has the most desirable features of the *Lycopersicon* types tested, it is being used in crosses with the hybrids possessing eelworm and fusarium-wilt resistance.

The hybrids from crosses between Hawaiian Experiment Station selections and commercial varieties possessing eelworm and fusarium-wilt resistance are being developed in conjunction with the Commonwealth Research Station, Merbein. Segregations for eelworm resistance are observed in seed-beds and in the field at Red Cliffs, Victoria. The segregations for fusarium-wilt resistance are followed in the glasshouses at Canberra. At Red Cliffs only hybrids combining resistance and desirable agronomic characters are retained.

(*e*) *Induced Autopolyploids in Pasture Species.*—The chromosome number has been doubled by the use of colchicine in twelve varieties of subterranean clover (*Trifolium subterraneum*), one line of white clover (*T. repens*), Hunter River lucerne (*Medicago sativa*), two lines of barrel medic (M. tribuloides), one line of *M. rigidula*, four lines of *M. hispida*, one line of perennial ryegrass (*Lolium perenne*), and one line of Wimmera ryegrass (*L. rigidum*).

Because colchicine frequently affects a sector only of treated plants, selection in the first seedling progenies is important. Selections were made in the first instance by measurements of stomata and pollen grains followed by chromosome counts. Anatomical and morphological comparisons are being made between the autopolyploids and their parent types. Some physiological aspects of the autotetraploids in subterranean clover are to be investigated.

4. PLANT DISEASES.

The work described in this Section is carried out in the Microbiology and the Disease Control Sections of the Division and concerns plant pathology, virus studies, pure culture collections, and antibiotics. Special attention has been given to virus diseases with the objective of control by chemotherapy.

(*a*) *Virus Disease—Plant Tissue Culture Techniques.*—(i) *Root Growth.*—When tomato roots infected with potato virus X were grown in culture the virus disappeared after about seven months. Further studies of persistence of both virus X and tobacco mosaic virus in tomato roots have been initiated with the object of finding whether these viruses can continue to multiply in roots kept in darkness or are dependent on exposure to light. Attempts to grow potato roots have been successful as a result of incorporating coconut milk in the medium.

(ii) *Virus Multiplication.*—A sterile clone of potato, variety Carman, has been developed and attempts are being made to grow these plants in full nutrient in complete darkness to study the effect of light on virus multiplication.

(iii) *Callus Tissue.*—Attempts to grow undifferentiated callus tissue of potato on solid media have not been successful, the tissue persisting for some time but ultimately dying.

(*b*) *Witches' Broom Disease of Lucerne.*—Further studies of the host range of this virus were made in the greenhouse, particularly to confirm its relationship to tomato big bud. It was shown that at least two strains of witches' broom exist, a severe strain and a mild strain. The severe strain appears to be identical with tomato big bud. The mild strain does not cause typical virescence.

(*c*) *Potato Diseases.*—Work on Common scab (*Actinomyces scabies*), *Rhizoctonia solani*, and late blight (*Phytophthora infestans*) has been discontinued.

(*d*) *Pasture Diseases in the Ninety-Mile Plain, South Australia.*—Two distinct types of bare-patch disease were shown to be present in pastures of subterranean clover. One of these was caused by *R. solani* and is identical with the "Purple Patch" disease of cereal crops. The other is caused by eelworms (*Heterodera* sp.). A third type of seedling failure tentatively called "General Unthriftiness", more widespread than the other two, has also been demonstrated. A field infection trial has given evidence that this condition is caused by *Corticium praticola*.

(*e*) *Antibiotics in Plant Pathology.*—Selective media for the isolation of *Actinomycetes* from soil have been developed in co-operative work with the Commonwealth Serum Laboratories and have been used in screening for antagonists against plant pathogenic fungi and bacteria. No isolate has shown sufficient promise to justify continuation of this approach.

(*f*) *Seedling Blight.*—The differential influence of some elements of plant food on the susceptibility of some hosts to seedling blight is being investigated. Observations indicate that the preceding crop influences the amount of seedling blight.

(*g*) *Take-all of Wheat.*—A comparative experiment of ten rotations in relation to take-all control is now in its fourth and final year. Another four-year experiment ending this season, will show the effect of nutrients in relation to the control of this disease.

5. FRUIT INVESTIGATIONS.

The work in the Division is confined mainly to apples and pears and is carried out at Hobart, Tasmania, and Stanthorpe, Queensland. A severe hailstorm in December, 1951, damaged most of the fruit at Stanthorpe. Investigations (*a*)-(*c*) below were made at Hobart; (*d*) and (*e*) at Stanthorpe.

(*a*) *Physiology of Apple Fruit.*—A survey of a range of varieties of apples at two crop levels was commenced in the 1950-51 fruit season. These were selected to cover a wide range of varietal characteristics and were examined for respiration rate, cell size, total and protein nitrogen, starch, and acid content. The principal conclusions of this survey (which was complementary to the investigations of the Plant Physiology Unit of the Division of Food Preservation) are: (i) difference in fruit size between light and heavy-crop fruit is a matter of cell size rather than cell number; (ii) varietal fruit size is mainly a matter of cell number; (iii) respiration rate per cell is closely related to cell volume both between crops and between varieties;

(iv) protein nitrogen is correlated with cell size, protein synthesis keeps pace with cell size increase between crops and between varieties; and (v) light-crop fruit has a higher respiration rate per unit protein than heavy-crop fruit and its shorter life and higher susceptibility to disorders may be due to this.

These results have suggested a new approach to the important commercial problem of improving the keeping capacity of large size fruit. Such an improvement is most likely to result when manurial and cultural treatments, designed to increase fruit size, increase cell number per fruit without increasing cell size.

(*b*) *New Investigations Commenced.* — Following the preliminary results of the above investigations, long-term new projects were commenced in the 1952 fruit season.

(i) *Variety Comparison.*—The study of the differences between light and heavy crops was continued on many of the varieties used during the previous year. The same trees were used so as to observe the alternation of cropping potential under different seasonal conditions.

(ii) *Progress of Maturation.*—Studies on the course of maturation, particularly in relation to cell size and respiration per unit protein, were commenced for light and heavy crops of four selected varieties.

(iii) *Breakdown Susceptibility in Relation to Respiration per Unit Protein.*—A preliminary attempt was begun to link these characteristics by a study of the progress of respiration and change of protein content during storage in relation to the development of breakdown in Cox's Orange Pippin, a highly susceptible variety.

(iv) *The Effect of Manurial Treatment on Cell Size and R/P Ratio in Relation to Keeping Quality.*—Uniform plots of Jonathan and Cox varieties have been obtained and a study of the effects of nitrogen level on these factors was commenced. Preliminary trials, to influence cell number per fruit by means of growth substances in combination with manurial treatment, have also begun.

(*c*) *Problems of Gas Storage.*—Experiments were conducted with seven apple varieties in 5 per cent. carbon dioxide at 33° and 36° F. compared with controls in air. Varieties, which had been tested by Tindale and Huelin in Victoria, behaved similarly in Tasmania. Of the varieties tested Democrat proved outstandingly successful and in gas storage showed improved flavour and texture, and less incidence of rots over those fruits held in air storage. Jonathan and Delicious in gas also showed improved performance over air, but the improvement was not as marked.

Other varieties were less successful, and therefore further trials are being carried out in other gas mixtures. Trials are in progress with Cleopatra, Jonathan, Golden Delicious, Geeveston Fanny, Delicious, Granny Smith, Crofton, and Sturmer, at 32°, 34°, and 36° F. and in two gas mixtures, 0 per cent. carbon dioxide: 5 per cent. oxygen and 5 per cent. carbon dioxide: 16 per cent. oxygen. Granny Smith unexpectedly developed severe scald even with oiled wraps. Tasmanian Pride developed a high incidence of breakdown in gas storage.

(*d*) *Rootstock Trials at Stanthorpe.*—A preliminary trial on the effect of rootstock on storage quality of apples was determined using Jonathans from trees on five rootstocks and Granny Smith fruit from trees on four rootstocks. The fruit was examined for firmness of flesh, a starch-iodine test was carried out at harvesting, and the incidence of storage disorders determined at the end of June.

Trials are also continuing on the effect of rootstock on fruit size, cell size, and the mean number of cells per fruit. Granny Smith fruits from three trees on each of four rootstocks were used.

(*e*) *Nematode Infestation.*—The problem of tree replacement in the Stanthorpe district has led to studies of the root lesion nematode, its effect on tree growth, and its control when replanting infested areas. A survey of the granite belt was carried out to determine the prevalence of the nematode in the district; and to determine the types of fruit tree susceptible to attack. All orchards showed the presence of *Pratylenchus* spp. in apple roots, although the extent of the infestation varied considerably. Plums and peach rootstocks showed resistance.

Soil sterilization carried out on pot experiments with infested soil showed that satisfactory growth of apple seedlings could be obtained after treatment with "D-D" and formalin. Sodium selenate proved toxic at the concentrations employed. Parathion showed some toxicity.

A microscopic examination of roots taken from the 24 rootstocks on the Station showed the presence of nematodes and eggs within the feeding roots of all roots examined. An examination of one-year-old apple trees showed that nematode infestation depresses the growth of seedlings.

It is likely that the prevalent nematode in the district is a new species as it differs from the common *P. pratensis.* It resembles *P. coffeae* but has a different host range. The survey of the nema fauna in orchard soils showed the presence of two predatory nematodes, *Aphelenchoides* sp. and *Monochus* sp. There are also many other mematodes previously unrecorded in Australia and these are being classified.

The search for alternate hosts has shown that linseed is very susceptible to attack. Infested plants are small and chlorotic, with lesions appearing within a week. The majority of weeds in the orchards show the presence of *Pratylenchus* spp. in the roots. Pots of infested soil kept moist but free of weeds have not yet shown any decrease in numbers of *Pratylenchus.*

6. Drug Plants.

Some of the investigations on drug plants are now being concluded. They are: (i) the study of *Duboisia* spp. as sources of hyoscine and atropine; and (ii) the study of varieties of opium poppy as sources of opium alkaloids. However, the systematic search for sources of supply of pharmacological and other useful chemical substances in native plants is continuing.

(*a*) *Survey of Native Plants for Substances of Pharmacological and Chemical Value.*—An Australian Phytochemical Survey which was commenced in 1946 has now located, tested, and examined several hundred plant species, mainly angiosperms, from tropical and subtropical rain-forests of Queensland and northern New South Wales. Alkaloids, various glycosides, saponins, steroids, triterpenoids, and pigments have been isolated and these have been characterized in other laboratories. During the year, 417 species were spot-tested and 111 bulk samples collected for analysis in other laboratories. The scope of the survey and progress to date are indicated in "Proceedings of the Third Phytochemical Conference" issued in 1951 Compilation of a Phytochemical Register is well advanced.

In addition to these chemical examinations and in collaboration with local or overseas laboratories selected plants have been investigated for pharmacological reasons, namely (i) principles responsible for poisoning in livestock, (ii) anti-mitotic and anti-cancer activity, (iii) steroids of a type suitable for the synthesis of cortisone, (iv) cardiac glycosides, (v) antibiotics, and (vi) active principles responsible for parasite-resistance in selected commercial timbers.

Quantitative analyses to determine fluctuations in hydrocyanic acid content of Queensland pasture plants and of introduced pasture species have been made throughout the past two years, and an attempt has been made to correlate these analyses with climatic factors and the stage of growth and other physiological factors.

Cardwellia sublimis (Proteaceae), northern silky oak, has been shown to contain aluminium succinate. This has taxonomic as well as physiological significance.

(*b*) *Phytochemical Survey — Papua and New Guinea.*—A reconnaissance survey was made of the phytochemical potentialities of the floras of Papua and New Guinea. Selected areas representative of lowland forest, foothill, mid-mountain, and highland forest associations were visited. On the basis of botanical affinities samples were sought of species belonging to certain families and genera which had yielded substances of chemical interest during the course of the phytochemical survey of the Australian flora. Particular attention was devoted to the family Rutaceae containing alkaloids and to monocotyledons likely to yield steroidal sapogenins.

Bulk samples of leaf or bark or both of the 27 most promising species were collected and 5-lb. samples of another twenty species which gave good positive reaction in field spot-tests, in addition to small samples of some 350 species. The majority of the samples are expected to contain alkaloids.

Whilst some collecting was done during this survey it was essentially a reconnaissance prior to more intensive detailed examination of selected areas. The Organization is indebted to the Administration of New Guinea and particularly to the Department of Forests for the provision of facilities during the course of the survey.

(*c*) *Testing Plant Material for Anti-mitotic Action.*—The testing of chemical substances and extracts obtained from native plants during the course of the Phytochemical Survey has ceased. One hundred and twenty-five substances were tested by determining their effects at varying concentrations upon mitosis in root tips of *Allium cepa*. The majority of substances at suitable concentration caused some aberrations in the mitotic process. A few caused marked aberrations over a wider range of concentrations.

On the basis of these tests and other criteria samples of 32 substances were sent to the Sloan-Kettering Institute for Cancer Research for ascertaining anti-tumour activity. Permission has been given to the Sloan-Kettering Institute to publish results.

(*d*) Duboisia *spp.*—The assay of experimental plant material by the chromatographic column method, commenced in May, 1951, is continuing. The tentative results to date have changed many ideas formerly held regarding the relationships of the alkaloids in the three major groups. The effect of external factors on the nature and the amount of the alkaloids has been studied from two aspects—

(i) *Mineral Nutrition.*—A sand culture experiment was commenced in the glasshouse using Phraglands Solution No. 1 adjusted to give (1) low nitrogen, (2) low potassium, and (3) low phosphorus.

(ii) *Interference with alkaloid metabolism by means of plant growth regulators.*—Maleic hydrazide and 2,4-D when sprayed on the leaves were without any effect on either the nature or the quantity of the alkaloids.

Studies on propagation have continued. The failure of Canberra-grown material to propagate vegetatively has been discussed in earlier Annual Reports. This problem has now assumed importance as it may preclude the commercial exploitation of heterozygous selections. It seems that the condition of the stock plants rather than the conditions under which the cuttings themselves are placed is the vital factor.

The problem of non-germination of what appear to be otherwise normal seeds has previously defied solution. What appears to be a germination inhibitor has now been demonstrated in the sarcocarp of the *Duboisia* berry. The work is continuing with particular emphasis upon the possibility of overcoming the inhibition of germination by some chemical treatment soon after harvest of the berries.

7. TOBACCO.

Laboratory investigations were continued at Canberra and field investigations in association with the Queensland Department of Agriculture at Ayr.

(*a*) *Quality.*—At Ayr the effects on leaf quality of three levels of nitrogen and three spacings were examined under field conditions. It appeared that nitrogen at 12 lb./acre was adequate for growth. At this or higher rates the yields per acre of good leaf were almost the same for the 20 and 15-in. spacings, but lower for the 30-in. spacing. For the same level of nitrogen per acre, quality was higher at the wider spacing, but treatments with greater amounts of nitrogen, at the 30-in. spacing, are necessary to determine the amount giving optimum quality. With the wider spacings there was a reduction in total yield, and an increase in the ratio of good to poor quality. The maximum quantity of good leaf was obtained at 20-in. spacing with nitrogen at 18 lb./acre. These observed effects are considered to be due to light, nitrogen, and possibly temperature interactions. Chemical analyses of leaf samples are continuing.

The distribution of plant roots under the several treatments was investigated, but the incidence of nematode infestation prevented satisfactory comparisons.

(*b*) *Varieties and Disease Resistance.*—Hybrids being tested at Ayr for mosaic resistance developed necrosis of the vascular tissue. This condition can occur in *Nicotiana glutinosa* and in *N. tabacum* hybrids containing the mosaic-resistance factor from *N. glutinosa*. Work is in progress to determine the conditions of inoculation and temperature that result in the development of stem necrosis.

Tobacco leaves from north Queensland are often excessively thin. The effect of colchicine-induced polyploidy on leaf thickness of two varieties is being examined.

(*c*) *Diseases.*—Investigations on yellow dwarf and big bud viruses were continued under greenhouse conditions. At present grafting and insect transmission are the only known methods for transferring the disease to healthy plants, but neither is satisfactory for large-scale experiments. Sap transmission of yellow dwarf, using cysteine hydrochloride as a reducing agent, is being tried giving special attention to the carborundum and pin puncture techniques, and to temperature and light before and after inoculation. Attempts to transmit yellow dwarf disease by means of the dodder species *Cuscuta campestris* were not successful and two other species of dodder are now being tried. Propagation by cuttings, with and without growth-regulating substances, is being done as a preliminary to the study of the distribution of the virus in the plant. In the search for resistance, twelve *Nicotiana* species have been tested and four appear to be resistant. Histological studies are under way to determine the plant tissues affected by the virus.

(*d*) *Work in Northern Territory.*—At Katherine an area of 17 acres was planted at the end of May and harvested during September-October. Yield of flue-cured tobacco of good colour was of the order of 1,000 lb./acre. An area of 4 acres was planted in June, 1952, to obtain more information on commercial possibilities.

8. General Plant Chemistry.

(*a*) *The Trace Element Content of Plants.*—A detailed examination of the trace metals copper, zinc, manganese, molybdenum, and iron in subterranean clover at various stages of growth is being made. Results at present available indicate—

(i) *Copper.*—The relative copper content of the whole plant decreases throughout the growing period. The copper content of the leaf always exceeds that of the stem, which is usually greater than that of the petiole. The copper content of the maturing seed and that of the peduncle are greater than that of the leaf.

(ii) *Zinc.*—The zinc content of the whole plant also decreases during most of the growing period, although it increases again during the later stages of growth. As with copper the zinc content of the leaf always exceeds that of the stem. The zinc content of the petiole material increases as the plant matures and generally exceeds that of the stem, while that of the peduncle decreases as the plant matures. The zinc content of the maturing seed decreases and is always much greater than that of any other plant part.

(iii) *Manganese.*—The manganese content of the whole plant decreases during the first haf of the growing period and then increases. The leaf material always contains more manganese than the stem and shows a fluctuation in manganese content similar to that of the whole plant. The manganese in the stem material tends to increase during most of the growing period, as does that of the petiole and that of the peduncle, both exceeding that of the stem.

(iv) *Molybdenum.*—The molybdenum content of the plant decreases very rapidly during the early stages of growth and then more slowly until the later stages of growth when it increases. The stem material always contains more molybdenum than the leaf.

An experiment has been commenced to compare the efficiency with which different varieties of oats can utilize copper and zinc.

9. Plant Nutrition.

(*a*) *Characterizing Deficient Soils.*—(i) *Field Experiments.*—Trials with potassium, copper, zinc, molybdenum, manganese, iron, magnesium, and boron on a number of soils on the Southern Tablelands of New South Wales have been maintained. Studies of deficiencies on these soils have been reported in a number of publications. Responses of subterranean clover and lucerne to boron have now been obtained on some of the soils, particularly on soils of sedimentary origin. Field trials with the essential elements are also in progress on soils of the Heytesbury area, Victoria, and at the F. D. McMaster Field Station, Badgery's Creek, New South Wales.

(ii) *Pot-culture Experiments.*—Responses to sulphur, phosphorus, and molybdenum have been compared on 32 soils in pots. The degree of correlation between the deficiencies and soil factors is being examined.

(iii) *Laboratory Studies.—Phosphorus:* The forms in which phosphorus occurs in soils are numerous and complex, and information on their nature and availability to plants has been obtained. However, an estimation of the amounts of available phosphorus is of little value in deciding whether or not plants will respond to applied phosphorus, except when considering similar soils. The relative availability of both natural and residual phosphorus in addition to the total amount present is determined by a number of soil factors such as pH/phosphate-absorption capacity, and the nature of the exchangeable cations. Experiments to examine the relative importance of these factors are in progress.

Sulphur: Little knowledge of the nature of sulphur in Australian soils is at present available. A semimicro fusion technique has been developed for the estimation of total sulphur in soils and experiments are being made to develop a technique for the estimation of organic sulphur in soils as a preliminary to an examination of the nature of sulphur available to plants.

Molybdenum: Much evidence is available of the importance of soil pH in the availablity of molybdenum to plants. However, it is evident that other soil factors also play an important part in governing molybdenum availability. Some evidence has been obtained that the free iron oxides of the soil may play an important part and glasshouse and laboratory experiments are in progress to examine this.

(*b*) *Factors Affecting the Supply and Availability of Elements in the Soil.*—(i) *Effect of Clover.*—The effect of a varying number of years of subterranean clover on the nitrogen status of the soil is being tested at Canberra. The subterranean clover is sown alone and in association with phalaris. The control plots are free from clover. Superphosphate and molybdenum are applied to all plots to correct deficiencies other than nitrogen.

(ii) *Combined Effects of Clover and Fertilizers.*—The effect of superphosphate on clover and subsequent development of grass has been examined on the soils of the Southern Tablelands. Some of the results obtained in this work have been published. The trials are being maintained for a second period of four years. The combined influences of superphosphate, subterranean clover, and time on the nitrogen, phosphorus, and sulphur constituents of podsolic soils derived from granite on the Southern Tablelands of New South Wales are being examined. While few results of this experiment are available, indications are that pasture improvement by the use of superphosphate and subterranean clover results in an annual increase in soil nitrogen equivalent to approximately 30 lb. nitrogen/acre.

(iii) *Soil Reaction.*—The effect of alkaline materials on the availablity of nitrogen and sulphur in local soils is being examined in pot culture experiments. The results indicate that lime increases the amount of available nitrogen and sulphur in these soils, but that the effect is small.

On basaltic red loam soils of the Lismore district, which contain a high percentage of phosphorus of low availability, alkaline materials had little or no effect on the availability of the phosphorus but increased the amount of available nitrogen. However, increasing the pH of the soil had only a small effect on the nitrogen deficiency.

(*c*) *Factors Affecting the Response to Fertilizers.*—(i) *Interaction between Elements.*—Interaction between elements has been obtained recently in a number of instances. At the Heytesbury area, copper had little or no effect where lime was not applied but gave a marked increase in the growth of clover in the presence of lime. On a soil on the Southern Tablelands, boron improved the growth of clover only where molybdenum was used. In pot culture experiments, poor responses of Paspalum to superphosphate on the red loam soils of the Lismore district were due to deficiency of nitrogen. The effect of sulphur deficiency on the response to rock phosphate is being examined.

(ii) *The Residual Effect of Fertilizers.*—The experiments to test the residual effect of superphosphate on soils of the Southern Tablelands are being maintained for a second period of four years. The results of the first four years have been published. Field experiments with molybdenum, boron, and copper are being maintained on different soils to determine the number of years over which these elements remain effective. Initial dressings of 2 oz. molybdenum trioxide/acre and 3½ lb. borax/acre applied in 1946 are still effective after six years.

(iii) *Form of the Fertilizer.*—The form in which phosphorus and sulphur may be applied is being examined. Various sulphates are being compared for immediate response and residual effects. The effect of rock phosphate and silico-super, with and without sulphur, is also being tested.

(*d*) *Characterizing Deficient Plants and Defining the Role of Elements in Plants.*—Information on the differences in the nutrition of various plant species is recorded in the experiments.

(i) *Mineral Content.*—Plants are selected from various experiments for determining the minimum amount of an essential element needed in the plant for maximum growth under particular conditions. Work with sulphur has shown that subterranean clover which has obtained sufficient sulphur for maximum growth may still be deficient in sulphur for protein synthesis. Experiments to determine where sulphur is deficient should therefore take account of the protein content as well as the yield of the plants.

(ii) *Plant Metabolism.*—Further studies are being made on the effect of molybdenum on the composition of plants, and on the role of molybdenum in nitrogen metabolism.

(iii) *Symbiotic Nitrogen Fixation.*—The effects of essential elements on symbiotic nitrogen fixation as distinct from their effects on the host legume are being studied.

(*e*) *Comparison of Species.—Factors Involved in the Distribution of Subterranean Clover and Medicago Species.*—Field observations indicate that the relative distribution of subterranean clover and *Medicago* species appears to be governed in some way by soil pH. It is unlikely that this distribution is governed by phosphate availability, and it was suspected that calcium carbonate in the soil may be an important factor. Subterranean clover and burr medic were grown on eight soils covering a wide range in pH from less than five to almost nine and containing varying amounts of calcium carbonate. There was little observable difference between the two species in their ability to grow on these soils. It would appear from the results of this experiment that soil pH is not the main factor in determining the relative distribution of these two species.

10. Tobacco Chemistry.

(*a*) *Light Factor in Development of Trashy Leaf Tobacco.*—Artificial shading of tobacco plants in the field in 1950-51, simulating the natural shading which occurs when plants are approaching maturity, produced leaf with the physical characteristics and chemical composition of naturally occurring trashy leaf. In comparison with non-trashy leaf the shaded leaf in the uncured and cured states contained less than one-quarter of the amount of sugars and possessed about 50 per cent. of the weight per unit area. This experiment confirms that reduction of light, due to shading in the field, as the crop increases in weight or from an overcast sky, is one of the most important factors leading to trashy leaf in Australian-grown tobacco.

(*b*) *Use of Fluorescence in Identification of Uncured Trashy Leaf.*—Analyses of over 1,200 samples from north and south Queensland, Northern Territory (Katherine), and Western Australia indicate that in any crop there are infinite gradations in the degree of trashiness and a gradual transition from one grade of leaf to the other is evident. Therefore, sampling into grades which is based on the physical properties of the leaf is difficult, particularly with uncured leaf, where often a large proportion of the leaf is left unclassified. It was observed that trashy leaf does not fluoresce under ultraviolet light, whereas non-trashy leaf produces brilliant fluorescence. Chemical examination confirmed the identification of the degree of trashiness determined by means of fluorescence. It is now a standard practice in this Laboratory, when sampling, to check and regrade uncured samples under ultraviolet light.

(*c*) *Effect of Pentose Sugars on Hexose Sugars—Anthrone Complex Formations.*—Absorption spectrum curves have indicated that, in the presence of pentose sugars, hexose-anthrone complex (H-A) is not formed and an entirely new molecular species is produced by the anthronation reaction. The newly formed complex appears to be of pentose-hexose-anthrone (P-H-A) type. It has a maximum absorption at a wavelength of 680 $m\mu$ and at equal concentrations produces 28 per cent. more absorption at 620-625 $m\mu$ than H-A, whereas the absorption power of pentose-anthrone complex at 620-625 $m\mu$ is less than 2.0 per cent. of H-A complex. This leads to new possibilities in determination of sugars and imposes limitations on unselective use of anthrone.

A chromatographic technique was adopted for separation of pentose and hexose sugars and their alcohols. In tobacco no sugars other than fructose, glucose, and sucrose were found in water extractions and only the first two after 0.7N sulphuric acid hydrolysis of the leaf.

11. Plant Physiology.

The Principal Physiologist is still stationed in Adelaide owing to lack of accommodation in Canberra.

Work has continued on correlative mechanism associated with and controlling plant development.

(*a*) *Photo-periodic Response.*—Under late spring-summer conditions *Echium plantagineum* L. has previously been shown to act as a long day (L.D.) plant, 6-8 exposures only to L.D. being necessary for floral initiation. Two further experiments were carried out under winter conditions, aimed at establishing the earliest stage at which the light stimulus may be perceived. These largely failed to give the required information, because it appears that *E. plantagineum,* unlike other L.D. plants investigated, is less (and not more) sensitive to exposures to L.D. at lower temperatures.

It has hitherto been accepted for L.D. plants that lowering the temperature acts equivalently to promoting the L.D. perception, and this point is basic to current theories concerning L.D. photo-periodic response. The present finding, if confirmed, must lead to revision of such theories.

(*b*) *Leaf Growth Factor.*—Further work was carried out on the system comprising the gramineous coleoptile and first leaf. Removal of the endosperm (grain) results in smaller growth of the first leaf, and, though this may naturally be attributed to removal of food reserves, it cannot explain a quite similar reduction in first-leaf growth when the coleoptile only is removed, in the presence of the grain. The magnitudes of these effects have been established quantitatively in relation to time of operation. The effect is greater the earlier the removal of either grain or coleoptile. The effect is still demonstrable, for coleoptile removal, at a stage so late that the coleoptile has ceased growth in extension and is approaching senescence.

These and other facts are compatible with the hypothesis that the coleoptile metabolizes some substrate of the endosperm and so produces a micro-nutrilite which is promotive for leaf growth. None of the following substances, supplied via the roots, appears able to substitute for this hypothecated system: various carbohydrates, simple nitrogenous compounds, amino acids (such as tryptophane, arginine, and ornithine), and purines (as adenine), singly or in combination, and in the presence or absence of indole-3-acetic acid. Attempts to isolate the responsible factor, either by diffusion into agar, or by direct extraction of seeds and coleoptiles of various ages, have been unsuccessful, and further intensive biochemical work would be necessary to characterize this substance more particularly.

Although much is known about the factors necessary for both root and stem growth, surprisingly little is known about leaf growth. The system described above provides some interesting leads to this subject and should merit further study.

(*c*) *Germination.*—The existence of an after-ripening period for seeds of *E. plantagineum* has been demonstrated. Immediately following harvest at full maturity seeds have zero germinability, and this rises steadily to 40-50 per cent. during the following 150 days. The failure to germinate immediately is not due to unfavorable water uptake (as proved by direct determination) nor probably to unfavorable conditions of aeration, since seeds, whose coats are chipped just prior to test, also have zero germination at harvest, though the germinability rises to approximately twice that of seeds tested in the intact condition over the same interval of time. Thus the primary ability to germinate appears to be under the control of another limiting factor, which acts as an inhibitor that gradually becomes dissipated or destroyed. The interest attaching to such natural inhibitors is that they probably constitute a secondary regulatory mechanism for the control of the main hormonal systems which are chiefly responsible for the integration of growth processes.

(*d*) *Ontogeny and Hormones.*—A method has been developed in which, by controlling the water supply, and humidity of the environment, plant organs of equal temporal age may be brought to different physiological ages. The system is proving useful in investigating the sensitivity of plant material to applied hormones.

12. TOBACCO PHYSIOLOGY.

Growth and development studies on tobacco have continued along two main lines: the first is concerned with factors associated with the vegetative phase and the transition into the reproductive phase of the autogenetic cycle, and the second with means of inhibiting or stimulating the growth of embryonic tissue.

(*a*) *Leaf Studies.*—(i) *Culture of Excised Leaves and Nodal Buds.*—As an outcome of studies on the effects of different levels of soil moisture on leaf development it was found desirable to culture isolated leaves. During the past year, root systems have been induced on cotyledons, leaves of the juvenile, vegetative, and reproductive phases, and on the pedicels of seed capsules. All types of leaves have been cultured, hardened, and maintained in a healthy state over lengthy periods.

(ii) *Shape and Area.*—The trend in the shape and area of the individual leaves of a plant, from base to apex, is a quantitative measure of the rate of aging. Tracings have been made of the leaves of: normal plants grown from seed; plants with alternate leaves removed; these excised leaves cultured separately (this gives a comparison between the intact series, the excised series, and each of these with the leaf development of the normal plant); and plants grown from seed but defoliated with the exception of a single leaf left at different nodal positions. All axillary buds are prevented from developing.

Leaf shape and number are affected by environmental factors such as temperature, light, and nutrients, but the physiological age of the meristematic tissue may also play a part. Series of plants have been propagated vegetatively. The physiological age of the successive nodal buds increases with height.

(*b*) *Inhibition or Stimulation of Growth.*—(i) *Control of Suckering in Tobacco.*—Laboratory work with growth regulators was followed by field trials in north Queensland in 1950 and 1951. More effective inhibition of sucker growth has been obtained by applying certain mineral oils to the topped plants than with any of the synthetic regulators. Concomitant with the effective control of suckers there is also a significant reduction in the incidence of trashy leaf.

Arising from the sucker control studies, a small pump was designed to fit on to a pair of secateurs. This enabled a predetermined dose of any liquid to be applied to the plant simultaneously with the excision of the inflorescence. Arrangements were made to manufacture this "applicator" under Provisional Patent No. 6211/*51*. It can also be used, instead of laboriously hand painting, for other plants which require the addition of chemical substances to cut surfaces.

(*c*) *Effect of Soil Moisture and Drought on the Growth of Tobacco.*—It was reported last year that a soil maintained below its moisture-holding capacity was more harmful to the growth of the plant than a series of droughts. Irrigation experiments are in progress at Ayr, Queensland, to confirm this observation under field conditions.

13. PLANT ECOLOGY.

A Plant Ecology Section is responsible for the classification of plant communities, analysis of their distribution in relation to environmental factors, studies of native grasses, and weeds investigations.

(*a*) *Regional Vegetation Studies.*—The survey, classification, and mapping of plant communities is in progress in the Southern Tablelands, Macquarie, and New England regions of New South Wales, south-western Queensland, and the rain-forest regions of Queensland. A survey of the vegetation of the eastern Riverina has been completed and is in process of publication. This work is reported under the pasture investigations of the regional centres, Sections 18, 19, and 21. In addition to the distribution of plant communities in relation to climate, soil, geology, and topography, the objectives of these studies include the determination of the effects of fire, settlement, and land use practices on the structure and composition of the communities.

(*b*) *Native Grassland Studies.* — (i) *Grazing Management Experiment, Trangie, New South Wales.*—This experiment, which is being conducted in co-operation with the New South Wales Department of Agriculture, is in its fifth year. The objectives are to determine the effects of sheep stocking rates, and of deferred and continuous grazing, on the yield and botanical composition of a native grassland dominated by *Stipa falcata-Chloris acicularis.*

During 1951-52 there was a marked decrease in mean plant density and in sheep body weights with increasing stocking rates; the basal area of perennial grass species also showed a reduction at the heavier stocking rates. Seasonal changes of soil moisture and soil nitrogen are being determined.

A subsidiary experiment was initiated in the autumn of 1952 to compare the carrying capacities of native perennial grasses with those of introduced winter annuals, principally *Medicago denticulata.*

Autecological studies of the principal grass species and investigations of the factors of scald formation are in progress.

(ii) *Grazing Management Experiment, Deniliquin, New South Wales.*—The grazing management experiment and autecological studies on *Danthonia semi-annularis* are discussed in the report of the Deniliquin Station (Section 17).

(iii) *Successional Studies, Canberra, Australian Capital Territory.*—The effect of complete exclusion of stock from a previously heavily grazed area of *Eucalyptus melliodora-Eucalyptus blakleyi* woodland has been studied for fourteen years. Changes in botanical composition of the grass layer from short to tall grasses, principally *Themeda australis*, have been recorded.

(c) *Ecological Studies on Weeds.*—Surveys of the distribution of skeleton weed (*Chondrilla juncea*) in relation to soil, climatic, and land-use factors have been commenced. Studies of the life history of the weed and of seasonal fluctuations in rosette populations in relation to soil nitrogen are in progress.

The effect of competition from introduced pasture species on the growth and development of skeleton weed are being studied at Cowra, New South Wales, and Canberra, Australian Capital Territory. At Canberra detailed studies of the competition factors between skeleton weed and each of three species, lucerne, subterranean clover, and *Phalaris tuberosa*, have commenced.

In Queensland experiments with competing plants for mintweed (*Salvia reflexa*) control have shown that nitrogen and sulphur applied to a mixture of native grasses and mintweed causes the weed to grow vigorously and compete with the grasses. However, the same fertilizers applied to a mixture of mintweed and a high fertility demanding crop or grass results in virtual suppression of mintweed.

14. CHEMICAL WEED CONTROL AND PLANT TOXICOLOGY.

(a) *Hoary Cress.*—Experiments in the Wimmera district of Victoria have shown that hoary cress populations can be reduced by 70-80 per cent. by light applications of methoxone or 2,4-D at one or two year intervals. The greater effectiveness of the second in comparison with the first application suggests that a further treatment may reduce hoary cress to negligible proportions. This is being investigated.

(b) *Skeleton Weed.* — Extensive experimentation during the last five years with a wide range of hormone-like herbicides has given no indication that adequate control of established skeleton weed can be effected by these compounds. However, substantial increases in yields resulted from light applications of 2,4-D to an infested wheat crop at Walla Walla, New South Wales; treatment eliminated part of the competition from skeleton weed and by reducing the growth of the weed greatly facilitated harvesting of the wheat.

(c) *Nut-grass.*—The use of trichloroacetates (TCA) and maleic hydrazide for the control of nut-grass is under investigation at Lawes, Queensland.

(d) *Woody Plants.*—Comparisons of a range of polyethylene glycol esters of 2,4-D and 2,4,5-T for the control of sweetbriar and blackberry are in progress at Canberra, Australian Capital Territory.

(e) *Grass Weeds.*—Successful control of rhizomatous grasses, such as Johnson grass and couch grass, has been achieved with trichloroacetates (TCA) at Canberra and Griffith. At the latter place further studies with TCA are in progress.

Studies of the herbicidal properties of petroleum oil fractions using *Paspalum dilatatum* as a test plant have been made over a four-year period and the results are in process of publication.

(f) *Aquatic Weeds.*—Investigations on the control of water weed *Potamogeton* spp. and *Vallisneria* spp. in irrigation ditches by 2,4-D, chlorinated benzenes, and solvent naphthas form part of a general study of aquatic plants at Griffith.

(g) *Evaluation of New Herbicides.*—Screening tests of new plant growth-regulating substances, " CMU ", maleic hydrazide, and " Endothal " using standard test plants are in progress at Griffith. New compounds for weed control have been tested at Canberra by their effects on the germination of wheat. 2,4-Dichlorophenoxyethyl phosphate exhibits similar characteristics to the sulphate; neither has an appreciable effect on established plants. Using beans as test plants the glycerol esters of 2,4-D proved superior to 2,4-D acid.

(h) *Eucalypt Regeneration.*—A number of experiments with hormone-type herbicides for the control of eucalypt regrowth have been conducted by the Division in Queensland. It appears essential for permanent control to destroy the lignotubers by mechanical methods.

(i) *Translocation of Herbicides.*—It was found that in winter there was no diurnal variation in remote toxicity of methoxone to bean plants. Previous work has shown diurnal variation in the summer.

Some evidence has been obtained that arsenic acid is not translocated in skeleton weed roots in the dark. Radiophosphorus was found to have no effect on the translocation of arsenic acid in skeleton weed.

(j) *Radioactive Tracers.* — Techniques have been developed for the determination of radioactive compounds in plant tissues. This work forms part of a programme for using tracing herbicides in plant tissues.

15. PASTURE INVESTIGATIONS AT REGIONAL CENTRES.

The agrostological work of the Division is carried out mainly at the various regional centres, but certain investigations are being undertaken on a co-operative basis with State Departments of Agriculture at their experiment farms, and on private properties. The chief objective of the Agrostology Section is the study of pastures from an ecological angle with the particular aim of increasing the carrying capacity.

Australian pastures can broadly be divided into three ecological units: an area of Mediterranean climate with a dominant winter rainfall, an area of more or less uniform rainfall, and an area of summer rainfall. Experiment stations have been established in each of these ecological zones.

The investigational work can be subdivided into—

(i) Ecological studies on native pastures, including regional surveys, grazing management trials, and regeneration studies.

(ii) Ecological studies of exotic pastures, including the selection and establishment of species, and their management under natural rainfall and irrigated conditions.

(iii) Pasture nutrition, including the study of mineral deficiencies on many soil types in problem areas of Australia.

(iv) Pasture chemistry, which includes chemical composition of pastures and chemical aspects of soil fertility.

16. PASTURE INVESTIGATIONS AT DICKSON EXPERIMENT STATION, AUSTRALIAN CAPITAL TERRITORY.

(a) *Medic Investigations.*—With the object of obtaining a suitable grazing legume for those parts of the wheat and sheep areas where conditions are unfavorable for subterranean clover, a large number of annual medics have been obtained from overseas and various parts of Australia and subjected to field trials in a number of places. The most satisfactory varieties to date are a vigorous strain of barrel medic (*Medicago tribuloides*) from Forbes, New South Wales, a spineless variety of burr medic (*M. hispida reticulata*) from Turkestan and a short-spined variety (*M. hispida terebellum*) from Malta. Nucleus stocks of seed have been built up at Canberra and distributed through the New South Wales Department of Agriculture for field trials on farmers' properties.

As persistence of medics is closely correlated with the production of hard seed, investigations have been carried out to determine the influence of environmental factors on the production of hard seed. It appears that the level of soil fertility and moisture during the growing period play only a minor role and the thoroughness with with the pods dry out at maturity is the main factor involved.

A trial to determine the influence of day length and air temperature on initiation of flowering indicates that only in a relatively small area of the far northern part of Australia would temperatures be unfavorable for flowering to occur, and that nowhere would day length be a limiting factor, so that possible distribution of medics throughout Australia would presumably depend upon level of soil fertility and rainfall.

(*b*) *New Introductions.*—Sward trials with promising grasses and legumes for pasture improvement suggest that at low to medium levels of soil fertility there are very few which are superior to those already in general use in the area of winter rainfall. Higher levels of phosphating are now being used to ascertain whether it will be practicable to hold certain species hitherto regarded as not permanent or to develop mixtures with a growth rhythm different from mixtures already in use or do both.

(*c*) *Management Investigations.*—A trial is in progress to determine whether the same amount or more herbage can be produced from a *Phalaris tuberosa*—subterranean clover pasture by sowing the grass in rows more widely spaced than 7 inches apart.

An investigation to determine the factors which influence the ratio of grass to clover in a mixed pasture of Wimmera ryegrass and subterranean clover has shown that the major factors are the level of soil nitrogen and phosphorus, and that grass dominance can be readily obtained and maintained if the pasture is liberally treated with superphosphate provided there are no other deficiencies of plant nutrients. Treatments such as surface cultivation are ineffective in permanently rejuvenating the grass component in a clover-dominant sward.

(*d*) *Fertilizer Trials.*—Application of superphosphate at various rates and times has shown that the total amount applied and not the time of application is the important factor in promoting the growth response of the pasture.

At Canberra, where lime improves the growth of lucerne, it has been shown that placement of this fertilizer is important. Incorporation in the soil to a depth of 6 inches at sowing gives better results than top-dressing afterwards.

Application of molybdenum oxide at the rate of 2 oz. /acre improves the growth of phosphated pasture at Canberra during the early years of development, but where soil nitrogen has reached a high level there is little measurable improvement. It appears that the molybdenum increases the rate at which the gramineous components assume dominance by increasing the efficiency of the legumes in building up liberal quantities of soil nitrogen. No improvement has been obtained from applications of boron, magnesium, potassium, zinc, iron, or copper to improved pasture at the Dickson Experiment Station. Manganese causes a depression in growth vigour.

17. Pasture Investigations at Deniliquin, New South Wales.

(*a*) *Native Pastures.*—Periodic visits have been made to the *Atriplex vesicaria* association to observe season floristic variation.

The grazing trial on native pasture has been continued. The autumn rainfall was low in 1951, and since pasture production was limited to the June-October period of five months, yields were comparatively low.

Many perennial grass seedlings (*Danthonia semiannularis*) were recorded, germination occurring during the winter period when the soil was saturated. Germination in protected areas was generally less than in grazed treatment plots. The perennial plants which were charted when the trial commenced in 1949 were drastically reduced in all treatments during the first half of the year, with a consequent reduction in basal cover. The absence of the summer species *Chloris truncata* and *Sporobolus caroli* was also due to seasonal conditions. Species which are selectively grazed by sheep have been observed each season.

The sheep flock has been in forward condition during the summer months, but at the onset of autumn or winter rain lost considerable weight. This seasonal body-weight loss is attributed to the deterioration of grass and herbage by rain. Heavy grazing of the shrub species *Kochia aphylla, Muehlenbeckia cunninghamii, Leptorrhynchus panaetioides,* and *Helichrysum apiculatum* occurs.

Studies of the soil moisture status of the "crab-holey" fine-textured clay soils have been made to determine its effect on species distribution. Observations on seasonal soil moisture variation under different pastures are continuing.

(*b*) *Plant Species and Strain Trials.*—(i) *Dryland Sward Trial.*—Thirteen strains were sown in a replicated sward trial on a coarse-textured levee soil. Clare strain of *Trifolium subterraneum* outyielded other legumes in the first growing season. *Lolium loliaceum* and *Bromus unioloides* were the only productive grasses. Annual species regenerated freely from seed in April, 1952.

(ii) *Medic Row Trial.*—Herbage yield and seed production of the following medics were measured during the 1951 growing season: *Medicago tribuloides, M. hispida terrabellum, M. obscura tornata, M. turbinata aculeata, M. orbicularis, M. blanchiana,* and *M. rugosa.*

M. blanchiana was the most productive species. All had matured some seed by October, and all except *M. orbicularis* regenerated freely in April, 1952.

(iii) *Winter Growing Species—Plot Trial on a Clay Loam under Autumn and Spring Irrigation.*—Sixty species or strains were sown in late April, 1951, the chief genera represented being: *Lolium, Phalaris, Festuca, Poa* and *Lathyrus, Vicia, Pisum, Medicago,* and *Trifolium.*

Avena sterilis, Hordeum sativum, Phalaris aquatica, and *Lolium multiflorum* yielded very heavily in the first season. *Vicia atropurpurea, Lathyrus tingitanus, Trifolium subterraneum,* and *Vicia dasycarpa* were the highest-yielding legumes. The Clare strain of *T. subterraneum* was the most promising clover, and *M. orbicularis* the most promising medic.

(iv) *Summer Growing Species—Row Trial on a Clay Loam under Irrigation.*—Of the 70 species or strains sown in November, 1950, the following failed to regenerate in the spring of 1951: *Pennisetum pedicellatum, Pennisetum* spp. 8328 and 8608, *Melinis minutiflora, Urochloa bulbodes, Setaria phragmitoides, Cajanus* spp., *Glycine* sp. 9466, and *Vigna unguiculata,* Yields above 120 cwt./acre were obtained from *Pennisetum purpureum, Sorghastrum* sp., *Echinochloa* *pyramidalis, Panicum coloratum, Paspalum dilatatum,* and *Sorghum almum,* when planted in rows 6 lk. apart. *Lolium perenne* strains made little growth after flowering in November. None of the legumes was productive in the second summer.

(*c*) *Plant Nutrition.*—(*i*) *Micro-element Pot Trial.*—*Trifolium hybridum* grown on Morago clay loam shows pronounced leaf bronzing and depauperate growth. The micro-element contents of the clover and its growth were compared on Morago soil and on Finley sandy loam, which is recognized as one of the most fertile soils in the district. The effects on the clover of adding a micro-element mixture to each soil were also tested. The sodium concentration in tops from the Morago soil was four times that in tops from the Finley. The micro-element addition tended to increase yields slightly on the Morago soil and decreased yields on the Finley.

(*d*) *Soil Structure and Root Growth Studies.*—(i) *Effects of a Rice Crop and of Gypsum on a Clay Soil* (*Type* R_2)—This experiment consists of two separate parts. In the first the component factors affecting the soil during the growth of a rice crop are separated for study by the treatments, namely, cultivation + inundation + rice; cultivation + inundation; and cultivation. In the second part leaching under rice is basal, and the effects of gypsum are examined.

Inundation during a single rice-growing season was found to have caused leaching of 40 per cent. of the soluble salts from the 0-30 in. depth. The pH (1:5) increased, reaching a maximum of 8.6 in the 12-21 in. depth. Inundation increased dispersion from 3 to 30 in. but did not increase dispersion in the 0-3 in. depth. Gypsum at 2 tons/acre reduced pH and dispersion at 0-3 in. although the total soluble salts were not increased. At 8 tons/acre, pH and dispersion had been reduced in the 0-3 and 3-12 in. depths and total soluble salts had been increased.

All treatments increased the calcium: sodium ratio of soluble and exchangeable cations, and decreased the amounts of soluble and exchangeable sodium in the 0-30 in. soil depth.

The root growth of rice is frequently credited with the power of opening up the surface of fine-textured soils. However, no difference in apparent density was found between clods taken from under a rice crop and clods from soil which had been inundated but not sown. Although 30 cwt./acre of oven-dry roots had been produced by the crop, the net addition of macro-organic matter to the soil was only 6 cwt./acre, root accretion having been balanced by the decomposition of organic residues present in the soil before the inundation period.

Two treatments were applied to the remains of the mature rice crop; namely, top growth removed, and top growth not removed; and the entire experimental area was sown to Wimmera ryegrass-subterranean clover pasture. The surface soil of the summer-inundated plots remained mealy and friable under the action of winter rains, but non-inundated plots slaked down. Water-stable aggregation at 0-1 in. was greater on the summer-inundated plots than on the non-inundated.

Where the tops of the rice crops had been left before disking, pasture yields were higher in the winter months but lower in the spring months than where the tops of the rice crop had been removed. Water-stable aggregation was greater, and nitrate production during incubation was less where tops of the rice crop had been left than where they had been removed. The experiment is being continued to determine the length of time that treatment differences persist.

(*e*) *Irrigation Hydraulics Studies.*—(i) *Infiltration*—A theoretical study of the movement of water into homogeneous unsaturated soils has been completed. A general equation has been derived which describes the downward entry of a liquid into such a soil in terms of the initial volumetric liquid content of the soil, and the viscosity and surface tension of the liquid. This equation appears to avoid certain objections to both the Horton and Kostiakov forms and enables the effect of antecedent soil moisture, temperature, depth of water on soil, and other physical variants to be evaluated.

An electrical model using Ohm's law as an analogue of D'Arcy's law has been used to evaluate the ratio of the final infiltration rate measured by the ring infiltrometer to the true final infiltration rate as a function of ring diameter and the depth to which the ring is driven. To date, the special case, analogous to a homogeneous soil closely tile drained, has been studied, and a ratio has been derived which has satisfied 525 cases representing five different ring diameters, twenty ring depths, and eleven tile drain depths.

(ii) *Irrigation Probe.*—Further work is being undertaken on the use of the irrigation probe as an index of soil moisture. A modified Proctor penetrometer is being used to measure the load exerted on the probe, and soil moisture determinations are being made at frequent depth intervals.

(iii) *Irrigation Hydraulics.*—Data from a number of border check irrigation runs have been analysed, equations relating aspects of the behaviour of the irrigating stream have been derived, and values of the constants in these equations have been determined.

18. PASTURE INVESTIGATIONS AT ARMIDALE, NEW SOUTH WALES.

(*a*) *Ecological Surveys.*—(i) *New England Region*—Of the 16,000 square miles to be covered in this survey, approximately 3,500 square miles of the southern portion of the region have been mapped. The mapping includes natural vegetation (plant associations and the distribution of the individual *Eucalyptus* species), soils, some geology, areas suitable for sown pastures, and location of existing sown pastures. The vegetation and soils pattern is exceedingly complex. Forty-six species of *Eucalyptus* have been recorded in the area mapped to date. This is an area of active speciation, hybridization being of common occurrence. The following soils have been recognized:—brown and red podsols; skeletal soils and lateritic podsolic soils derived from granites, sedimentary rocks, and basaltic parent material; colluvial; laterized; and alluvial and *in situ* basaltic soils.

(ii) *South-western Queensland.*—The area included in this survey is approximately 63,000 square miles. It extends north-westwards from the north-western boundary of the New England region and thence westwards between the State boundary and the Western Railway in Queensland to the Warrego River. Preliminary reconnaissance has been completed, and the broad relationships between vegetation communities and the major soil groups have been established. Detailed mapping of the soils and vegetation has begun, and so far 250 square miles have been covered.

(*b*) *Grazing Management Studies of Native Pastures.*—Native pastures, though low in productivity, form the basis of the wool-growing industry in the New England region. For economic reasons they are likely to remain so for some considerable time, although it is possible to replace them by more highly productive sown pastures. In co-operation with the Division of Animal Health and Production (*see* Chapter VII., Section 19 (*b*)), a study is being made of the effect on the sheep and on the pasture of different rates of stocking, continuous *v.* rotational grazing, and size of flock. A record is obtained of the effect of the different grazing treatments on: (i) infection by internal parasites; (ii) wool production; (iii) live weight, growth, and behaviour of the sheep; (iv) yield and botanical composition; and (v) chemical composition of the pasture.

The experiments are now in their fourth year and the decreased amount of total forage under the heavy grazing treatment, reported in the third year, has continued and has become more marked. No differences in the effects of continuous and rotational grazing have been recorded in the pasture, nor in the amount of total forage present under grazing by different sizes of flock when each is grazed at the rate of one sheep per acre.

The results from one season's observations have shown that the crude protein and phosphorus contents of the green material in the pasture have a marked seasonal trend, being highest in the spring. The legumes contained about twice as much crude protein as the grasses and miscellaneous (herbage) species. The calcium content of the miscellaneous species and legumes was considerably higher than that of the grasses.

(*c*) *Improvement of Native Pastures.*—With large areas of steeply undulating to hilly country, where cultivation in preparation for sown pastures would be attended by risks of severe erosion, there is need for a method of pasture improvement that does not employ ploughing. The basis of such a method is the inclusion of legumes, combined with applications of superphosphate, into the native pasture sward.

Investigations of suitable legume species, method and time of sowing, the effect of different degrees of cover of native species, and the effect of fertilizers are in progress. Subterranean and white clovers have been successfully established in dense native pasture, with the application of superphosphate. With the establishment of a dense stand of clover the density of the native species is often reduced, but the forage value of those species which survive and grow in association with the clover is increased. Increases of up to 80 per cent. of protein in native grasses and over 100 per cent. in a native herbage species have been recorded.

(*d*) *Species and Strain Trials.*—Because of the favorable rainfall conditions of the New England region, the scope for substitution of high-producing sown species for the relatively unproductive native pastures is great. Considerable effort is directed to the assessment of the productivity and the general agronomic characteristics of a number of pasture species at various localities in the southern part of New England.

The testing of forage grasses and legumes is carried out in rows and in swards. A number of species has now been under test for four years. After several years under sward conditions, and in association with clovers, several grasses, which in the early years were not productive, have now come into prominence following a build-up of soil fertility. The most outstanding are strains of tall fescue and smooth brome grasses from the United States of America and some perennial ryegrasses. These have outyielded *Phalaris tuberosa.* Cocksfoot and short rotation ryegrass have also been productive in summer and winter respectively.

Tallarook and Bacchus Marsh subterranean clovers and crimson clover continue to give slightly greater production during the cold winter period than red and white clovers which are productive at other times. For all-round productivity, and particularly as a means of raising the soil fertility, perennial clovers, e.g., white clover, have proved most successful on the tablelands of the region. On the granitic soils of the drier western slopes annual clovers have proved best. Tallarook subterranean clover has consistently outyielded others in this area.

Despite one of the driest spring and early summer periods on record, the survival of most of the perennial species was high. White clover sustained the greatest mortality, but sufficient plants survived to maintain satisfactory pastures. Red clover, *P. tuberosa,* cocksfoot, and tall fescue withstood the drought without loss.

(*e*) *Nutrition Studies.*—A survey of the plant nutrition status of the main soils of the region is in progress. Sulphur deficiency appears to be widespread in New England soils, and the effectiveness of several forms of added sulphur is being investigated. At one centre gypsum is proving effective as a source of sulphur, while at another, early response to sulphur is obtained only when ample phosphorus is also added. With a world shortage of sulphur restricting superphosphate production alternative sources of phosphorus are required. Rock phosphate is being tested as a source of phosphorus and gypsum as a source of sulphur.

Fertilizer trials carried out over the past four years have demonstrated marked responses by pasture species to the application of superphosphate. Whilst the largest increases, up to twentyfold, have been recorded for some granitic soils, some increase in production has resulted from applications of superphosphate on all soil types tested.

Stopping the applications of superphosphate, even after four years of annual application, results in a decline in forage yield and the entry of weeds into the pasture. There is evidence that this decline is due to an insufficiency of sulphur, normally met by the superphosphate.

With increasing rates of application of superphosphate (up to 2 cwt./acre) the seed yield of subterranean clover has been increased. Late summer or early autumn applications of superphosphate are producing a greater yield of winter forage from a *P. tuberosa*-subterranean clover pasture than from applications made in the late autumn.

Investigation of the factors responsible for improved clover growth on burns, suggest that this is not due to the addition of mineral nutrients from the ash, but rather, to an effect of the heating. Experiments are still in progress.

19. Pasture Investigations in Western Australia.

(*a*) *Grazing Management Trial, Perth.*—An experiment, conducted at Perth, involves a comparison of continuous and autumn-deferred grazing on a sown annual pasture with Merino wethers. Three grazing seasons have been completed. Sheep data obtained from the 1951-52 season agree with those of the previous year, namely, rapid gain in body weight under continuous grazing soon after the opening rains, slightly higher mean body weights in the deferred group throughout the growing season, and a lower rate of loss in weight under deferred grazing during the late summer. As in the previous years, the proportion of Wimmera ryegrass and capeweed was higher, and that of *Bromus gussonii* much lower under continuous grazing. The proportion of subterranean clover, whilst lower than in the 1950 growing season, was appreciably greater under deferred grazing.

(*b*) *Grazing and Rotation Trial, Wongan Hills.*—This co-operative investigation conducted at the Wongan Hills State Department Research Station is being continued. The effects of the several pastures on carrying capacity, sheep body weights, and wool production during the 1951-52 season agreed with the results of previous years, even though the botanical composition of the volunteer pasture had changed considerably during the course of the experiment. The second cycle of this trial is nearing completion.

(*c*) *Species and Strain Investigations.*—(i) *Phalaris tuberosa*—A study on the effect of row spacing on yield and persistency of spring sown phalaris is being continued at Glen Lossie Field Station, Kojonup. Yield data obtained at the end of the 1951 growing season indicated that row spacing as such did not materially influence the yield per unit area, although inter-row cultivation (in the widely spaced rows) gave an appreciable increase in production.

(ii) *Subterranean Clover.*—A number of introduced strains from the Mediterranean region are being compared with Australian strains. The results so far indicate several promising introductions for the Kojonup district.

A sward trial involving fifteen selected strains is being continued. Yield data at the end of the 1951 growing season showed the superiority of a number of strains over the locally grown Dwalganup. The early mid-season strain, Port Fairy, was again outstanding, especially in its re-establishment after the opening autumn rains in 1952.

(iii) *Cereals.*—Further wheat variety trials at Kojonup have confirmed the superiority of Gabo and Wongoondy amongst the early varieties, and Eureka and Yalta in the mid-season varieties. In a time-of-planting experiment, the varieties Gabo and Wongoondy produced higher grain yields than Eureka and Yalta, irrespective of the date of sowing.

The oat variety Orient, included in a grazing and recovery trial, was outstanding with a grain yield (52 bus./acre) well in excess of the remaining five varieties tested (25-34 bus./acre).

(*d*) *Plant Nutrition Studies.*—(i) *Pot-culture Trials*—Investigations on phosphorus toxicity in subterranean clover have been completed. Using a wide range of phosphorus levels and a number of contrasting soil types, the high susceptibility to phosphorus toxicity of subterranean clover grown on Muchea sand was confirmed. It was shown that on this particular soil type the "fixation" of phosphorus in forms unavailable to the plant is extremely restricted. In a further experiment it was demonstrated that phosphorus toxicity led to a reduction in net assimilation rate.

Studies of the factors affecting zinc responses in subterranean clover were commenced. Current results indicate that three strains of subterranean clover (Dwalganup, Yarloop, and Bacchus Marsh) are of approximately equal susceptibility to zinc deficiency under a range of moisture and light intensity conditions. The effects of moisture supply, light intensity, and applied nitrogen are being examined more extensively on the Dwalganup strain.

(ii) *Fertilizer Field Trials.*—An experiment on the effect of varying rates of potash fertilizer on the growth of three strains of subterranean clover (Dwalganup, Yarloop, and Bacchus Marsh) was completed. There was no significant interaction between levels of potassium and strain. A marked residual effect of potassium in the year following application was shown.

The effects of a range of sulphur and phosphorus levels on the yield of a subterranean clover pasture were examined at Kojonup. The relative response to sulphur was independent of phosphorus supply, increasing markedly up to ½cwt./acre gypsum, and increasing only slightly from the ½ to the 2 cwt./acre level. The relative response to sulphur decreased during the latter part of the growing season. The effects of varying rates of superphosphate applied annually are still under examination. There is evidence that the residual effects of superphosphate on Kojonup gravelly sand decreased markedly in the second year after application.

(*e*) *Soil Fertility Studies, Kojonup.*—Experiments were started at the Glen Lossie Field Station, Kojonup, on the influence of legumes (in particular, subterranean clover) on soil fertility build-up. The influence of the age and productivity of a subterranean clover pasture, varying rates of superphosphate application, and the rates of seeding of subterranean clover on soil fertility will be followed over several years. A comparison of annual grain legumes will be made in a number of legume-cereal rotations. The effect of continuous cereal cropping on an established subterranean clover pasture is under examination.

20. PASTURE INVESTIGATIONS AT BRISBANE AND LAWES, QUEENSLAND.

(*a*) *Ecology.*—The ecological survey of the coastal region from Brisbane to Bundaberg was continued. Approximately 4,000 square miles of country have been subdivided into eight smaller "suites" and tentative boundaries have been established.

Four major types of vegetation have been recognized; in order of importance: (i) open eucalypt forest, (ii) tea-tree formations, (iii) heath, and (iv) wallum. The true wallum country occupies only a small proportion of the total area whilst the heath type is less important than either of the forest types.

As existing rainfall maps do not show sufficient data (e.g. incidence and intensity of rainfall) a new rainfall map is being compiled from the monthly records at 300 stations. The Organization is indebted to the Queensland Forestry Department for information and co-operative services.

(*b*) *Regional Trials.*—(i) *Coastal.*—Pot trials have shown that forest soils are deficient in nitrogen, phosphorus, potassium, copper, molybdenum, and possibly zinc. Peaty soils from the tea-tree forest are deficient in nitrogen and phosphorus, and there was evidence of copper and zinc deficiency.

Typical sites were selected at Beerwah and Elimbah (forest), and at Glasshouse Mountain (tea-tree), where a limited number of field experiments have now been planted, using appropriate fertilizer treatment. Five legumes, *Phaseolus lathyroides*, lucerne, *Stylosanthes bojeri*, *Indigofera endecaphylla*, and *Desmodium uncinatum*, have made promising growth.

(ii) *Subcoastal.*—Severe drought in the central and subcoastal regions prevented the establishment of several regional trials planned for 1951, and imposed severe conditions on existing trials at Calliope and Rodds Bay.

Pot experiments with soil from Rodds Bay disclosed deficiencies of phosphorus, potassium, and molybdenum. A nursery trial with 17 legumes and 16 grasses was commenced. An area of 250 acres of typical cattle country is being used to establish a suitable pasture for animal experiments.

(iii) *Darling Downs.*—At "Anchorfield" (near Brookstead) and at "Woodlands" (near Cambooya), areas of up to 100 acres of row-lucerne have been established during the past 5 years. They made satisfactory and valuable regrowth during the year, and their value under adverse conditions is now established. A small area (10 acres) of *Paspalum scrobiculatum*, which was planted at "Anchorfield" in 1950, has made consistent and valuable regrowth during the summer months and under severe drought conditions. In soils that were treated with ammonium sulphate in January 1951, natural regeneration of *Phaseolus lathyroides* was recorded.

During the year, trials determined on the basis of pot experiments were planted at 13 widely scattered centres, within a sector of 250 miles radius from Lawes, stretching from Taroom in the north, through Surat in the west, and to Boomi and Texas in the south. Five broad soil types were represented. Ten grass species including *Paspalum scrobiculatum*, *Chloris gayana*, *Panicum maximum* var. *trichoglume*, *P. antidotale* (buffel grass), *Cenchrus ciliaris*, and three legume species, lucerne, *Desmodium uncinatum*, and *Phaseolus lathyroides*, were used in trials at 12 stations.

At five stations nursery rows were sown with approximately 45 grass and 40 legume species. Eighteen of the grasses belonged to the genus *Paspalum*, other genera were *Digitaria*, *Panicum*, *Cenchrus*, *Sorghum*, and *Pennisetum*. The legumes included both pasture species (*Stylosanthes* and *Desmodium*), green manure plants (*Dolichos* spp.), forage crops (*Vigna* spp.), and browse plants (*Cajanus* spp.). In most cases, despite severe drought conditions, good establishment was achieved.

(*c*) *Native Pasture Studies.*—Investigations of the effect of burning or the absence of grazing or both were continued. It was shown that in the absence of grazing the amount of pitted blue grass (*Bothriochloa decipiens*) has steadily increased in relation to the total basal area of other species, and that the proportion of bare ground has increased. Burning increased the amount of bunch spear grass (*Heteropogon contortus*) and burnt plots tend to resemble the existing monospecific pastures of the typical cattle country.

Chemical analyses of both native and exotic species show: (i) the better quality of species on the more fertile black soils, and (ii) the greater nutritional value of exotic species during most months of the year.

(*d*) *Sown Pastures.*—(i) *Rhodes Grass Pastures.*—Following appreciable increases in the liveweight of animals and in the yield of Rhodes grass from pastures incorporating a small amount of lucerne, field experiments have been conducted to measure the residual effects of these pastures on soil fertility. Crops of both sorghum and oats gave appreciably increased yields and it was shown that this effect of the mixed pastures persisted for at least two years.

In a study of the factors contributing to this difference in soil fertility, it was found that in plots previously under Rhodes grass pastures the weight of organic matter was about 4½ tons/acre, whereas in plots previously under Rhodes and lucerne pastures, it was about 7 tons/acre.

Pot experiments are in progress to measure the effects of the differing amounts and quality of organic matter on subsequent yields, the time necessary for effective decomposition of this organic matter, and the longevity of any change in soil fertility. A similar series of experiments is in progress to determine the effects of organic debris (fallen leaves and stems) on soil fertility.

(ii) *Pastures of* Paspalum scrobiculatum *and of Lucerne-Row Cultivation.*—An experiment designed to study growth and productivity in pastures of *Paspalum scrobiculatum* and of lucerne which commenced in 1948 has been continued during the past year. Results so far have shown that: (1) the carrying capacity of pure lucerne pastures is less than that of *P. scrobiculatum* alone or either of the mixed pastures; (2) in lucerne pastures cumulative yields from swards and from rows at 42 and 63-in spacings tended to a common level over a period of twelve months; (3) the quality of feed in lucerne pastures was better than that in other pastures, but the efficiency (i.e. yield of animal product/acre) was low; (4) within the three grass pastures, the yield of *P. scrobiculatum* exceeded that of the mixed pastures during the first year, but in this—the third year—yields from "grass alone" and from "grass and *Phaseolus*" were very similar, and the yield from "grass and lucerne" as not significantly lower; (5) in these three pastures the yield from rows at 63-in. spacing has been consistently below that of rows at 42-in. spacing, and is in conformity with the number of rows per acre, and the results of earlier experiments, but the yield from swards has increased steadily from the level of 63-in. rows in 1948-49 to that of 42-in. rows in 1950-51; and (6) the quality (i.e. nitrogen content) of grass pastures was improved in rows at wider spacing and this was reflected in better sheep weight gains.

It was shown that *P. scrobiculatum* draws very lightly on conserved soil moisture in winter (i.e. when low temperatures restrict new growth). An experiment to measure the effect of close cutting or grazing on the subsequent vigour of *P. scrobiculatum* has been completed.

(iii) *Associate Pasture Studies.*—Associated pastures wherein one or more pasture species are grown as separate stands and grazed by animals with free or restricted access to two or more such units have been developed. These have followed successful field trials in which beef cattle have been grazed on associated pastures of native grasses and row lucerne.

(*e*) *Plant Nutrition Studies.*—Plant nutrition studies were continued on (i) black soils from the Darling Downs and from South-east Queensland, (ii) soils from the coastal region, and (iii) the soil-plant cation relationships.

Chemical analyses of plants showed that sulphur has a direct bearing on the assimilation of nitrogen in plants grown on Darling Downs heavy clay soil. Application of sulphur (in almost any form) to this soil has induced fourfold increases in the yield of *Phaseolus lathyroides,* and a sevenfold increase in the yield of protein per acre. The effect of sulphur deficiency are very pronounced in terms of both yield and symptoms of malnutrition; only 20-40 lb./acre are necessary to promote healthy growth of both legumes and non-legumes.

With non-legumes there is also a deficiency of available nitrogen. Optimum dressings of sulphur and nitrogen have induced a threefold increase in the yield of *Paspalum scrobiculatum,* with again, a sevenfold increase in the yield of protein per acre.

It was found with wheat that, whereas nitrogen and sulphur increased the yield of flag and stem, nitrogen alone increased both the yield and quality of grain. In the absence of nitrogen, much of the grain was mottled and the baking quality of flour was markedly inferior. This suggests that on these soils, a pasture phase is essential to correct land usage and the maintenance of soil fertility.

The extent of the double deficiency of nitrogen and sulphur was studied in trials with black soil from different centres. Similar responses were obtained in samples from Lawes, Laidley, Beaudesert, Goomburra, Clifton, Kingsthorpe, Warwick, Dalby, and Taroom. In experiments with sandy soil (i.e. from Yandilla and Grantham) the same deficiencies were recorded. However, in these cases the problem is complicated by further deficiencies of essential elements. In one case it was found that satisfactory growth of grasses could be achived only with the addition of nitrogen, sulphur, and phosphorus and that for the satisfactory growth of legumes, molybdenum also was necessary.

(*f*) *Pasture Chemistry.*—Studies on the chemical composition of both native and introduced pasture plants were continued to determine criteria for the evaluation of species grown under "nursery" conditions. Experiments involved a comprehensive survey of the ratio of digestible protein to starch equivalent in a wide range of species at all stages of growth and under various cutting and grazing treatments. It seems that a reliable standard procedure, involving simple yet regular chemical analyses, can be developed to provide a reliable criterion for either under-grazing or over-grazing on existing pasture experiments.

21. Pasture Investigations at Cunnamulla, Queensland.

(*a*) *Grazing Management Studies.*—A grazing management experiment commenced in 1940 to compare the effect of light, medium, and heavy rates of stocking Mitchell grass pasture under both continuous and rotational grazing by sheep, was concluded in October 1951. The results of this long-term trial are being prepared for publication.

22. Pasture Investigations at Ayr, Queensland.

The Land Research and Regional Survey Section is co-operating with the Queensland Department of Agriculture and Stock in investigations on tropical pasture mixtures under irrigation in the Burdekin valley. These investigations include preliminary trials of pasture grass and legumes, including species not in commercial use, as well as some established ones, and a beef cattle grazing experiment with five grass-legume mixtures.

Regular samplings have been made in the pasture experiment, which has been grazed continuously on a fixed rotation throughout the summer of 1951-52. All pastures were reasonably well established when grazing commenced, but are now showing very different reactions to the environment and to grazing. For instance, Rhodes grass is being invaded by *Heteropogon contortus.* Para grass in Para-Centro (*Centrosema pubescens*) mixtures has grown better than in Para-*Clitoria* mixtures. The legumes, especially Centro, appear to have a stimulating effect on the grass closely associated with them. The pastures have not been stocked to capacity, but, at the rate of 1 beast/1¼ acres, the gain in weight has been of the order of 1.3 lb./week over the whole period since September 1951. The actual rate of increase has varied markedly from day to day.

An attempt to record soil moisture by means of Bouyoucos-type plaster blocks failed and the blocks were found to have partially disintegrated.

23. Katherine Research Station.

The Katherine Research Station is situated in the dominant soil type of the district—Tipperary red loam, derived from limestone; experiments are dependent on natural rainfall. Tobacco investigations on the Katherine River levee are being conducted by the Division of Plant Industry (*see* Section 7 (*d*)).

Records taken on the levee show that the rainfall during the 1951-52 " wet " season was the lowest since readings first began in this district in 1884. Only 13.63 in. was recorded as compared with the average value since recordings began of 35 in. A feature of this season's rain has been its patchiness.

(*a*) *Soil Fertility Studies.*—The 1950-51 season was, on the whole, very favorable for crop production and indications from fertilizer experiments were that the levels of fertilizer applications judged as adequate from previous experience were inadequate under favorable conditions. The recent " dry " wet season has emphasized the dependence of fertilizer response on rainfall, and it seems desirable to study the application of fertilizer in small amounts, repeated as rainfall and growth justify further additions.

Generally speaking, phosphate is the only fertilizer which gives any response in the absence of other elements. Nitrogen (as ammonium sulphate), which gives little response in the absence of phosphate, may produce a response as great as or even greater than phosphate in the presence of phosphate. Potash (as sulphate) has so far given indecisive, but mainly negative results, even at high nitrogen and phosphate levels.

Under good conditions, virgin soil requires a minimum of 3 cwt. superphosphate plus 2 cwt. sulphate of ammonia for optimum non-legume growth. Legumes, such as peanuts, require 2-3 cwt. of superphosphate plus some nitrogen—about 1 cwt. of ammonium sulphate.

No response has yet been obtained to a very wide range of minor elements with either sorghum or cowpeas. Elemental sulphur (in the presence of superphosphate) has given no response with peanuts or cotton. Lime or woodash may cause a marked drop in yield of sorghum in the presence of superphosphate.

Experiments on fertilizer placement with peanuts have shown no significant difference, but with sorghum, applications of fertilizer under the seeds or in side bands after planting have both proved significantly more efficient than placement between seeds in the planting furrow.

Residual fertilizer effects appear to be marked and must be considered in fertilizer programmes for older cultivations.

(*b*) *Soil Moisture.*—It is becoming apparent that the controlling factor in plant growth on the red soils is water, and that this fluctuates rapidly and widely. The soil is normally free-draining, but is very easily surface-compacted, e.g. by heavy rain, so that water runs off. The field capacity is low and the wilting point is high so that the soil has a very limited effective water range. Moreover, the soil, at least in the surface layers, dries out with great rapidity, so that within a few days of a soaking rainfall, the top 6 inches or so are too dry to support plant growth. Further evidence of the very limited storage capacity is the rapid shut-down of all crops once the rains cease.

(*c*) *Cultivation Practices.*—A continuous cropping experiment, using peanuts and cotton, has now produced its third crop. Crops have increased progressively. The effect is more strongly marked with peanuts than with cotton, but even with cotton the older cultivations have given two and a half times the yield of the new plots. Some of the effects of continued cultivation may be due to residual fertilizer, but this could only account for a small part of the observed effects.

Cultivation during crop growth has, especially in a dry year, marked beneficial effects up to a point when surface crusting is prevented and weed growth is kept down. Cultivations in excess of this minimum do not seem to have any significant effect.

(*d*) *Crop Investigation.*—All crops have suffered severely from birds and drought. Much information has been gained on drought resistance. Of all the crops grown, Kenaf (*Hibiscus cannabinus*) has shown the greatest resistance. It germinated well, and kept on growing when all other crops except peanuts were wilting badly. However, its final height of about 4 feet was much less than might be expected in a normal year. Peanuts showed remarkable drought resistance at all stages, but the drought, disease, and bird damage reduced yields very markedly. Some of the new introductions showed up remarkably well under these adverse conditions and, if the nuts produced are acceptable commercially, they should be a valuable addition to the whole area. Cotton, once established, showed fair drought resistance and produced a crop which, however, was of little value, since the lint was not more than ½ inch long instead of the normal length of approximately ⅞ inch. The 1950-51 cotton crops were ratooned at the end of the season, in the hope of getting large plants and rapid cropping in the following wet season. Only the early planted cotton (1950) survived the 1951 dry season, while cotton planted in the early months of 1951, although producing reasonable crops in that season, failed to survive the dry period. It is presumed that the older plants had developed deeper roots and so tapped moisture reserves unavailable to the younger plants.

Sorghum was found to be highly susceptible to drought in the seedling stage, but once established, showed tolerable drought resistance.

Sunflower crops failed completely in the seedling stage. Several *Phaseolus* species of the gram group were tried, but were not very successful. Again the seedling stage appeared most susceptible to drought.

The past wet season's results have emphasized the difficulty in getting good stands of crops, and have shown quite clearly that the methods employed in preparing the seed bed are of major importance. It is believed that crops such as sunflowers and sorghum could be grown successfully in very dry conditions, once an initial stand had been established.

(*e*) *Pasture Investigations.*—The two main objectives of this work are (i) to devise suitable mixtures for sown pastures as part of a rotation in cultivation, and (ii) to increase the productivity or quality or both of the natural pastures.

A grazing trial on a block of mixed introductions during the 1951 dry showed that after a good wet season a carryover of some 200 steer grazing days/acre was available. An attempt was made to extend the area of sown pastures during the 1951-52 " wet ", but the grass seedlings failed to establish themselves. From plot observation, the most promising species for sown pastures would appear to be *Cenchrus ciliaris, C. biflorus,* and *Urochloa bulbodes.* Of the legumes so far tried, including Townsville lucerne (*Stylosanthes sundaica*) which is susceptible to shading, *S. gracilis,* and *Clitoria ternates,* only Townsville lucerne has shown promise in mixtures with these grasses. It is more successful under heavily grazed and low fertility conditions. The grasses which show most promise of being adapted to the environment are not rated highly on a palatability basis. Attempts are now being made to combine grasses and legumes in a pasture on a row basis. Of the legumes so far investigated, Townsville lucerne appears to be outstanding in its adaption to the requirements of the locality. Its yield varies considerably with rainfall and fertility, but in a normal season, 10-15 cwt. dry matter/acre can be expected from an unfertilized natural pasture plus an unkown, but appreciable, bulk of seed, while with superphosphate and cultivation these yields can be raised very appreciably. The plant begins to flower and to produce seed while still very small, and so even in bad seasons continuity is assured. Seed collection is by means of a subclover sheepskin roller.

In grazed native pastures, cattle do not graze Townsville lucerne until it begins to dry off with the coming of the dry weather. The preferential grazing of the grasses during the " wet " favours the establishment of Townsville lucerne, and in time the legume completely suppresses the grasses. Weed invasion would probably follow. If a satisfactory grass can be found for reseeding, the point where Townsville lucerne has suppressed the native grasses and is not yet invaded by weeds seems to be the logical time to sow such grasses.

Peanuts do not offer much promise as a pasture legume, as stock and birds dig out the nuts in the dry weather and so destroy continuity.

(*f*) *Pests and Diseases.*—Apart from damage by birds and by wallabies, which has been unduly heavy in the last year as a direct consequence of the drought, cotton and peanuts have suffered damage. Cotton crops in the past have been remarkably free from pests and this has encouraged an attempt to increase yields by ratooning. This year crops were heavily attacked by jassids, stainers, and bollworms, the attacks beginning on the ratooned cotton. It is quite clear that a rigid close season must be enforced during the dry winter months if cotton pests are to be successfully controlled. Peanut diseases are the cause of appreciable losses throughout the area. Failure to germinate, a frequent cause of bad stands in the area, appears to be due to improper storage conditions. Another common disease, hitherto known as " crown rot ", brings about a sudden collapse of the plant at any stage of growth. Some of the recent peanut introductions show a good degree of resistance to this trouble, and it may well be that the answer to the disease lies in a change of variety. The Katherine area has so far been singularly free from disease, apart from this one.

24. KIMBERLEY RESEARCH STATION.

The Kimberley Research Station, on the Ord River, is maintained jointly by the Government of Western Australia and the Organization, the Land Research and Regional Survey Section being responsible for the technical aspects of plant investigation. The immediate objectives are to determine whether the Black Soil Plains of the Ord River are satisfactory for irrigation, and whether a stable system of agriculture can be devised. The district is at present devoted to extensive cattle raising, and so considerable emphasis has been placed on the development of irrigated pastures. The rains failed during the 1951-52 wet season and associated climatic conditions were far from favorable for crop growth. The weather remained hot, with strong, scorching winds, so that natural vegetation had dried out some two months ahead of its normal time.

(*a*) *Fertility Problems.*—All crops require phosphate for satisfactory growth, the amount required ranging from 2 to 3 cwt. superphosphate/acre. There is only minor response to nitrogen in the absence of phosphorus, but there is usually a fair response to 1 cwt. ammonium sulphate in the presence of phosphorus. Potash has given indecisive and conflicting results. There has been no response to a wide range of minor elements. Yields vary widely from one experiment to the next, but the best yields obtained for all crops are very high, e.g., peanuts, 3,500 lb./acre and sorghum 5,000 lb./acre. In spite of these high yields, non-leguminous crops invariably have a pale yellow-green colour, in contrast to the legumes, which are a full deep green. Grasses, which start off well, fall away rapidly after the first year of growth, and pastures become decadent even before they are well established. This is not entirely due to shortage of phosphorus or nitrogen, for they show no appreciable response to added fertilizer, and there is no obvious soiling effect where cattle have grazed.

Tufted grasses tend to develop large, relatively isolated stools which seem to inhibit the establishment of seedlings in their vicinity. Elephant (*Pennisetum purpureum*) and Sudan grass (*Sorghum sudanense*) have both strongly inhibited the growth of lucerne 7 feet away. There is, moreover, a very marked border effect with these grasses, which cannot be due to competition for water, since these plots were regularly irrigated. Grasses growing in close association with *Clitoria ternatea* have shown a marked improvement in both colour and vigour, but this has not yet been noted to apply to other legumes.

The physical structure of the soil probably accounts for declining fertility. When freshly cultivated it produces good crops, but after several wettings it becomes compacted and a very shallow, but extensive rooting system develops.

(*b*) *Pastures.*—It has been found expedient to establish irrigated pastures in the cool season when competition from annual weeds is greatly reduced. This finding would also appear to apply to pure stands of *Clitoria ternatea.* New pastures were established of *Panicum maximum* (Guinea), *Brachiaria mutica* (Para), *Paspalum scrobiculatum* (scrobic), *Andropogon gayanus,* and *Cenchrus ciliaris* Type B. Grazing began in December and continued throughout the wet season. As long as there was adequate palatable and nutritious material, all these grasses, with the exception of *Cenchrus,* gave rise to very good liveweight gains; *Cenchrus* proved most unpalatable and cattle readily lost weight on it. *Clitoria* appears particularly palatable, and so far it has combined well with both tufted and decumbent grasses. *Stylosanthes gracilis* was slower to establish and has not been so palatable nor so vigorous as *Clitoria.* The clump grasses, Guinea and *Andropogon,* both grow rapidly during the wet season.

In the normal wet season, it would be unwise to put cattle or equipment onto the soft, wet, sticky clay and as a result, these grasses may well get out of hand. Their habit of forming large, dense, and well separated stools would add to the difficulties of controlling them mechanically.

The best stand and the best pasture were obtained with scrobic, but after the first few grazing periods, it has shown a marked decline in colour and vigour. In this it is behaving in exactly the same way as Rhodes grass, which showed good promise at the start, but rapidly declined after reaching an early peak. A wide range of grasses and legumes is under trial in plots; among the grasses *Panicum* sp. aff. *coloratum*. *Digitaria* sp., and *Setaria sphacelata* show promise. Lucerne has persisted better than formerly, probably because of the dry "wet" season and the relative absence of grasshoppers.

A cutting trial with fodder grasses has shown that a 28-day cutting interval is better than 42 or 56 days, having regard to both quantity and quality of material and to persistence of stand.

(*c*) *Crops*.—Peanut yields from irrigated crops during dry seasons have not been satisfactory, and during the past wet season, with its low rainfall and its lower than normal humidity, the supplementary irrigated peanut crops also gave less than their normal yields. Variety trials have shown that some of the newer introductions can outyield the standard varieties, and arrangements have been made for the commercial appraisal of these promising new varieties. Sorghum and rice yields have both been severely handicapped by bird damage. Rice has been particularly affected as ducks grazed the seedlings and were followed by a general bird attack on any grain appearing. Cages covered in ½-in. mesh wire are being erected.

Sunflower, safflower, and linseed have all shown some promise as dry season irrigated crops. Jute was grown for the first time, and yielded some 12 tons of green stems per acre. Better results might be expected in a more humid season. Cotton trials have continued to be sorely plagued by pests, and yields have been far below what they might have been. Even so, a mean yield of seed cotton of 600 lb./acre was obtained. The most promising crop so far appears to be sugar-cane, which this year covers an area of 1¾ acres. Growth to date is very promising.

(*d*) *Irrigation*.—Field capacity determinations made shortly after irrigation have given a mean value of approximately 27 per cent. Sugar-cane has shown distress when the soil moisture content has fallen to 19 per cent., indicating a range of only 8 per cent. of available moisture. This is an unexpectedly low value for a heavy clay; it is similar to values recorded for other soils at Katherine and on the Burdekin River in Queensland. As a consequence of this low available moisture, irrigations in the dry season must be at frequent intervals; for cane, an interval of a fortnight has been adopted. When seedlings are emerging, waterings at intervals of a few days are necessary to prevent the formation of a hard surface crust, which stops seedling emergence. Some trouble has been experienced with restricted lateral seepage, when using furrow irrigation with row crops, and it has been found that the finer the soil tilth prepared before planting, the better the lateral seepage. When allowed to dry out under fallow, these black soils crack extensively and deeply and it has been found essential to pre-irrigate such land before commencing to work it.

(*e*) *Pests and Diseases*.—Ducks, cockatoos and finches played havoc with the grain crops. Shooting did not deter them—they just left one part of the plot for another. Crows caused considerable damage to peanuts by digging them out of the rows and by taking them from stooks after harvesting. Cotton had its usual wide range of pests which probably migrate in from the wild malvaceous plants in the area. A sudden outbreak of looper caterpillars defoliated the jute crop in February, but was rapidly brought under control with DDT. Witches' broom affects most legumes to some usually very small extent, but can on occasion reach serious proportions as it did this year on a *Phaseolus* pulse trial. Stylo and *Clitoria* have so far been free of this disease.

The most serious disease on the station is known as "crown rot" in peanuts. An *Aspergillus* sp. has been found associated with all diseased material, but whether this is in the nature of a secondary invader, following on damage through some factor not yet known, is not clear. Plants are attacked at all ages, and in the past season, the greater part of a 6-acre planting on virgin land was attacked shortly before it was ready for harvest. The attack broke out at many points almost simultaneously. Some of the newer introductions show high resistance to the disease.

25. REGIONAL SURVEYS.

In addition to agricultural research at field stations in northern Australia, the Section conducts resources surveys of large underdeveloped regions in Australia, Papua, and New Guinea in collaboration with other Divisions and Commonwealth Departments.

(*a*) *Barkly Region*.—A comprehensive report has been prepared on the Barkly region. The origins of the various lands have been studied and the lands classified on this basis into 21 geomorphological units. Further subdivision into 38 land systems has been made on the basis of present topography, soils, and vegetation. In addition to the geomorphological maps previously reported, a traverse map and a map of land-use groups, with a descriptive table, have been prepared.

(*b*) *Ord-Victoria River Region*.—The second field season in the survey of the drainage basins of the Ord and Victoria Rivers in the east Kimberleys and north-west of the Northern Territory was commenced in May, 1952. The field work in this region will be completed by September, 1952.

(*c*) *Fitzroy River Region*.—A preliminary reconnaissance survey of parts of the Fitzroy River region in the west Kimberleys has been made as a result of a request from the Western Australian Minister for Agriculture. This reconnaissance was made during the current field season by a small group of officers. Attention was paid to the flats of the Fitzroy, Barker, and Lennard Rivers.

(*d*) *Papua-New Guinea Resources Survey*.—At the request of the Department of Territories a new unit is being organized to undertake a long-term resources survey of Papua-New Guinea.

26. MINERAL NUTRITION OF PLANTS IN THE COONALPYN DOWNS, SOUTH AUSTRALIA.

Plant nutrition investigations in the Coonalpyn Downs have been developed in two stages by the Division of Biochemistry and General Nutrition. In the first stage, the limitations imposed by zinc, copper, and phosphorus deficiencies in Laffer sand were proved, and the adaptabilities of subterranean clover and several other species to conditions there, when these deficiencies were made good, were demonstrated. In the second stage, questions relating to the application of the findings to farm practice have been investigated in a series of experiments conducted in several different soils. This latter stage is nearing completion and it is now becoming possible to recognize general principles of manuring, selection of species, and compounding of seed mixtures for developing permanent pastures on this terrain, and to recognize modifications of these procedures that are necessary in the various circumstances met with in soils differing widely in physical nature.

Experiments are in progress in the Coonalpyn Downs, in an area of light sandy soil near Coombe, to determine the effect on subterranean clover of dressings of zinc sulphate both lighter and heavier than the usual one of 7 lb./acre. Zinc deficiency has been found to be very acute in this particular soil. Early results indicate that the most beneficial dressing is between 7 and 14 lb. $ZnSO_4.7H_2O$/acre. With dressings less than these there is no reduction in the clover population during the first year, but plant size is reduced leading to reduced yield per acre. With dressings in excess of these, up to a maximum of 126 lb. $ZnSO_4.7H_2O$/acre, there is also a reduction in yield per acre, but here plant numbers are reduced while plant size is unaffected.

In Buckingham sand, where zinc deficiency has been found to be incipient rather than acute, early results indicate that from $3\frac{1}{2}$ to 7 lb. $ZnSO_4.7H_2O$ is sufficient to prevent the occurrence of zinc deficiency in subterranean clover.

Further seedings have been made of the species of grain legumes that had previously shown greatest promise in Buckingham sand. A large proportion of the experimental area became flooded during the very wet winter of 1951 and comparative yield data were unobtainable. The ripe grain was harvested where possible to provide supplies for further comparative seedings and to provide data relating to variability in average seed size.

Several long-term experiments conducted in various soils in the Coonalpyn Downs have been completed during the year, and progress has been made in preparing the results for publication.

The already very extensive development of the Coonalpyn Downs is increasing rapidly with spectacular results.

27. Sampling and Estimation.

Precision in sampling and in quantity estimation are important and not easily achieved requirements of agrostological and ecological studies. Attention has been given to these requirements by the Section of Mathematical Statistics.

(*a*) *Sampling of Pastures and Arable Crops.*—The problem of securing accurate estimates in the sampling of pastures and large plots of arable crops is one which has engaged much attention from agricultural experimentalists. In addition to using such devices as stratifying the area to be sampled, methods, such as visual matching of samples for estimation of production or consumption by stock, or the visual rating of quadrats on a scale which is calibrated by cutting a representative number of these, have been employed.

A quadrat of 1 sq.m. appears to be about the most convenient for pasture sampling which involves close clipping. The coefficient of variation associated with this quadrat size ranges from about 17 per cent. for yields of 40-50 cwt./acre, to 40 per cent. or more for yields of 5 cwt./acre or less. In view of this variability, some workers have used visually selected "representative" samples in an endeavour to achieve higher precision. However, this method involves a serious risk of introducing a bias of unknown degree in the estimation of total yield and that of particular species.

Re-investigation of the problem has resulted in the development of a new sampling technique, which secures increased precision by ranking quadrats in order of yield (but does not require an assessment of absolute yields). The new method gives an unbiased estimate of yield, and under general conditions is nearly $\frac{1}{2}(n + 1)$ times more accurate than the mean of n samples taken at random.

(*b*) *Estimation of Plant Density using Line Transects.*—In ecological studies, the line-transect method for the estimation of percentage ground cover by different plant species in a stand is well established as efficient in theory and practice, especially where marked aggregation of species occurs. The method has now been more closely investigated, to determine whether line-transect data can be employed in the estimation of plant density in conjunction with the estimation of ground cover. For relatively homogeneous stands or for studies of change at fixed sites, the square quadrat seems to have the advantage. For surveys in heterogeneous stands, the transect, in conjunction with the strip quadrat, will give unbiased and efficient estimates of density and cover. For established perennials in open shrub or grassland communities, having plants of fairly regular shape, cover and density of each species can be estimated from the transect chords. With moderately irregular boundaries, the density may be estimated using supplementary data on longest chords parallel to the transect from a subsample of the plants intersected.

IV. IRRIGATION.

1. General.

The principal units of the Organization for irrigation research are the Commonwealth Research Station (Murray Irrigation Areas), Merbein, Victoria, and the Irrigation Research Station (Murrumbidgee Irrigation Areas), Griffith, New South Wales. The work of these stations is reported in this Chapter. Much of it is especially relevant to the problems of the regions in which they are working.

Irrigation studies have also been made at Deniliquin, New South Wales, Ayr, Queensland, and the Kimberley Research Station, Western Australia.

2. Commonwealth Research Station (Murray Irrigation Areas), Merbein, Victoria.

Investigation of problems associated with irrigation in the middle and lower Murray River valley is the chief concern of the Merbein Station. Most of the settlements in the region served are devoted to horticulture. Because of the dominance among the horticultural crops of vine fruits for drying, special attention is given to the growth cycle of the sultana vine. Each year the Station's assessment of the potentialities for the ensuing season, based on microscopical examination in May of the dormant sultana buds, is awaited with great interest by growers, packers, and others associated with the dried fruits industry.

(*a*) *Irrigation, Soil Preservation, and Reclamation.*—Spray irrigation, of citrus and vegetables particularly, is expanding in the Murray region. Most of the recent work of the Station on irrigation technique has therefore been in this field. Several types of equipment have been examined with varied operating conditions to define the pattern of water distribution, rate of application, and drop size. Drop sizes are determined by the use of filter paper impregnated with rhodamine dye. An assessment has been made of the evaporation effects during the application of irrigation water by sprays.

Work is continuing in association with Central Experimental Workshops towards the development of a meter capable of accurate measurement of small and large flows of irrigation and drainage waters. Officers of the Division of Plant Industry at the Regional Pastoral Laboratory, Deniliquin, have found the original type of rotor meter developed at the Station very useful for measurement of water flows of the order commonly used on irrigated pastures.

During replacement of the open channel irrigation system on the Station vineyard by concrete pipe lines, a trial was made of cementing the outlet valves directly to the pipes and controlling the outflow of irrigation water by means of keys inserted down the centres of tile upstands. Although cheap to install, valves so placed proved too difficult to clean. The practice was therefore abandoned in favour of installing outlet valves at the tops of galvanized iron risers from the concrete pipes.

For those irrigated lands which have developed waterlogging and soil salinity problems, and which show no effective response to tile drainage, an economic alternative is being sought. The chief method under consideration is pumping from deep-seated sand strata, thereby inducing a drop in the level of the water-table within the overlying clay horizons located within, or immediately below, the root zone of crops. At present this work is centred in the Renmark district, where four bores to depths of about 80 feet have been made by a commercial bore-drilling unit and developed for pumping.

The determination of soil moisture status is of special importance in irrigation. Studies are continuing on the use of foamed concrete and plaster blocks for the measurement of soil moisture and moisture potentials. The electrical resistance of such a block varies with the moisture content of the soil with which it is in contact. Sensitivity of the foamed concrete blocks tried so far has been less than that of plaster of paris blocks, particularly in the high moisture range.

Examination of the Station records has shown that there is a highly significant correlation during the irrigation season between hours of bright sunshine and evaporation from a standard evaporimeter tank.

(*b*) *Land Use.*—The Station continues to carry out soil surveys of small areas within its region; during this year, a total of about 100 acres was examined, and many other matters concerning soil classification were investigated. Investigations in the area served by the Wakool Land-use Committee have been continued, with special reference to changes in soil conditions as the result of irrigation.

Now in its fourth year, the renovation trial on land at Woorinen, previously abandoned for vine-growing, showed a poor strike of lucerne sown over the whole area of the trial in autumn 1951. This was associated with a very wet winter following the sowing. Resowing of lucerne where necessary has been done in autumn this year. Examination of soil samples taken after this trial had been in progress for two years has shown that treatment has reduced soil pH level by 0.4 unit. A similar but smaller trial on the Experiment Farm of the Nyah-Woorinen Inquiry Committee continues to maintain satisfactory cover under the original pasture and lucerne treatments.

Vines on deteriorated lands at Woorinen were selected for trials of soil amendments but their variability is so great that statistically significant results are hard to find. These trials are now in their third year; they include gypsum and sulphur as the chief soil conditioners. A cultivation experiment has been superimposed on one of these trials as a split-plot treatment. The effect of controlling weeds by oil spray will be compared with control by cultivation. A new trial has been started at Koraleigh, where gypsum and oil spray are again the major treatments.

(*c*) *Horticulture.*—Growth phases of the sultana vine have been the subject of detailed studies for many years. Since 1945, sultana vine canes, sampled to represent the Sunraysia district, have been examined microscopically in May to determine the percentage of the dormant buds which will throw a fruitful shoot in the following season. For the crops havested under good weather conditions in 1951 and 1952, the yields fitted well with expectations based on percentage fruitfulness of the buds examined in the previous winters. The bud examination made in May, 1952, indicated 70 per cent. fruitfulness, while the mean bunch primordium size was 0.322 sq. mm. Both values are the highest obtained during the past seven years. The indications are that a very big crop of sultanas could eventuate if good weather prevails next season.

Observations on time of bud burst of sultanas were extended to three district blocks on a range of soil types. Examinations were made at intervals of three days. On all blocks, negative correlation was found between time of bud burst and salt content as indicated by analyses of leaf petioles in summer. On two of the blocks the correlation was highly significant, on the third it was not significant. Confirmation of a previous finding that fruitful shoots tend to burst earlier than unfruitful shoots came from two of the blocks, but at the third block on the heaviest soil type there was no difference.

The pruning trial on sultanas, in which the chief variable is the number of canes, all equal in length, per vine, again showed increased yield with increased number of canes. However, yield was not proportional to the number of canes; individual bunches of fruit were heavier on the vines carrying the smaller number of canes. In another sultana pruning trial in which the number of buds per vine was kept constant and the treatments consisted of varying inversely the number of canes and length of cane per vine, it was found that there was no significant difference in yield between the treatments in the first year's harvest.

Cincturing the sultana was investigated earlier and, in general, found unsuitable, except for fresh grape production, but a long-term trial has now been started to find out whether cincturing the sultana is economical in dried fruit production if performed in those years that follow a previous winter examination of the dormant buds which forecast a low yield. Results of the first harvest in this trial show the expected large increases in green weight of fruit and in berry size due to a double-cut cincturing, as compared with uncinctured vines. This practice, however, decreased sugar content, so that the increase in dry weight of fruit was smaller than that in fresh weight. A single-cut cincture had no effect in any of these respects.

With the currant, investigations are continuing on the replacement of cincturing, traditionally necessary for this vine, by spraying with hormone-like chemicals. The chief information is coming from an area of about two acres of currants in a private vineyard. Currant vines sprayed with 2,4-D according to the Station's recommendations at the time they would normally be cinctured yielded slightly better this season than similar vines cinctured in the usual way. The fruit, too, was not damaged as badly by rain before harvest. Pruning weights this winter showed that the sprayed vines had made considerably better annual growth during the past season, confirming observations of much better vigour in the sprayed vines last summer.

Occasional infestations of vines with mealy bug have been observed in the region in the past few years. A trial was made of various insecticides for the control of mealy bug on sultana vines. The insecticides tried were "Hexone", DDT, "Lime Sulphur" and kerosene. These were applied in August. Sultana bunches were examined just before harvest. It was found that mealy bug infestation had been increased where DDT spray had been used, but there was no significant difference from the untreated control where the other prays had been used. Detailed examination of the distribution of mealy bug population throughout the est area showed that bunches near trellis posts uffered infestation to significantly greater extent than hose remote from the posts. The posts should herefore be cleaned thoroughly by suitable spraying when the vines are dormant.

A third survey has been made of Woorinen vines and soils, this time in December, since work at the Station has shown that this is the best time to sample vines for salt status. Analytical work is in progress on pH and salt content of these soils and on boron and chloride content of the vine foliage.

Further work has been done on the relation between the salt status of the sultana vine and yield. Both drained and undrained sites on light, medium, and heavy soils in the Merbein district have been examined to find whether the leaf chloride value above which yield is depressed varies with soil type. Results suggest that the petiole chloride threshold value is independent of soil texture in the range of soil types studied. When the petiole chloride value (chloride ion in over-dried tissue) is above 1.6 ± 0.1 per cent. on undrained soils and above 2.1 ± 0.1 per cent. on drained soils in early December the sultana vine yield is depressed, the percentage reduction rapidly increasing with increasing leaf chloride. Severe leaf burning of sultanas in December under saline conditions means that yields are likely to be reduced heavily. Moderate burning of the leaf margins at that time is not a reliable guide to the prospects of effect of salinity on final yield. By means of foliar analysis at that time these prospects can now be evaluated with much closer precision.

A "no cultivation" trial on sultana vines at the Station was begun last winter. A treatment in which there is no cultivation, weeds being controlled by oil spray, is being compared with normal cultivation, including green manuring, and with two treatments involving white clover, one of which will carry white clover for the duration of the trial, in the other the clover will be turned in once every four or five years.

Determinations of boron on sultana vines in the manurial trial at the Station indicated that fertilizer treatments incorporating nitrogen and phosphorus had some effect in increasing boron content. No such effect was apparent for fertilizer potassium. There was no correlation between boron content of sultana leaves and their chloride content. Further investigations on the appearance of boron toxicity symptoms on vine leaves indicated that very few leaves containing over 200 p.p.m. boron in the oven-dried tissue did not exhibit symptoms.

Investigations of the practice of green manuring have been continued. With tick bean, the possibilities have been explored of growing this standard green manure crop on Mallee soils without annual use of superphosphate. Results so far obtained indicate that annual use of phosphate is necessary for maximum growth of green crop; there are notable differences in growth within a month of sowing on areas where phosphate has been withheld from certain treatments

Further work on *Lathyrus ochrus*, a green manure introduced into the region in association with the Division of Plant Industry, has confirmed previous findings that this is a valuable crop under certain conditions, particularly on light sandy soils. On the heavier soils provided with sufficient water, tick bean may produce a greater bulk of dry matter, but its nitrogen content is lower than that of *L. ochrus*. The chief value of the new green manure is its prolific seed production in this region, whereas tick bean does not set seed here. At Red Cliffs a trial is in progress with various seeding rates and spacings of *L. ochrus*. Seed productions will be measured from this trial.

Investigation of blossoming and fruiting of citrus in the Merbein district indicated that most of the fruit was set by flowers opening not earlier than mid-October. The flowering period lasted from the end of September to the end of October. Most fruit was produced by the second, third, and fourth flowers on the shoots; terminal flowers produced very few oranges on shoots which had more than one flower. Setting of the navel oranges was very poor, but the Valencia set was comparable with other seasons of good crops.

Weekly measurements of circumference of Valencia oranges were continued through 1951 and have been undertaken again this season. Despite a wetter winter in 1951 than 1950, a serious growth recession occurred, possibly attributable to low temperatures. Similar slowing of growth rate under conditions of ample moisture has already been noted in the 1952 season.

(*d*) *Plant Nutrients.*—Field trials on sultana vines using commercial fertilizers are being continued and extended. For the trial on soil of medium texture, ammonium sulphate gave its usual response again last season. A further trial on time of application of ammonium sulphate showed in 1951 an increase in vegetation growth only of sultana vines; for the 1952 harvest an increase in fruit yield was obtained also. On light soil at West Merbein, ammonium sulphate gave in the 1952 harvest its first response in yield of sultanas since this trial was laid down in 1948. Results for 1952 on light soil at Red Cliffs appear to confirm earlier findings of lack of response of sultanas to ammonium sulphate at this site.

To elucidate this variability in response of sultanas to nitrogenous fertilizer on light and medium soils of the region, trials of rate of application of ammonium sulphate have been commenced. These trials include three levels of applied ammonium sulphate and three levels of green manuring. Nitrogen nutrition of the vine has been studied by analyses of sultana leaf petioles. Petioles taken from the manurial trial at the Station in October showed nitrogen contents highly correlated with manurial treatment. Petioles taken in November from several high-yielding sites in the Merbein district showed no significant differences regardless of manurial treatment. It appears that the nitrogen requirements of the sultana vines at each of these sites were being satisfied by the existing practices, which varied considerably.

Some experience was gained last season with the use of the tissue-testing methods developed by Nicholas. These were applied to leaf samples from the manurial trials on sultanas at the Station. Tests for phosphate, chloride, calcium, magnesium, potassium, and nitrate were made. No unexpected results were obtained. It was found that reproducible results could be obtained from fresh samples, but that storages of this type of tissue for more than one day leads to considerable variation.

The rate of accumulation of nitrogen in the annual growth of the sultana vine and its distribution among the component parts of that growth were followed last season by examination of an area on the Station at fortnightly intervals. The indications from this replicated experiment are that nitrogen accumulates at a rather steady rate from bud burst to harvest. The data assembled for each vine in the experiment include the number of canes laid down in the previous winter, the number of shoots in the growing season, and the number of bunches harvested. These will be considered in relation to the variations of yield and nitrogen contents of the vines.

Work on the effect of zinc application on berry development and yield of the Gordo blanco grape has continued. The chief point of interest is the effect on the zinc content of the canes and leaves of swabbing pruning cuts with zinc sulphate.

(*e*) *Vegetables.*—In the 1950-51 season, investigations were commenced on the extent of hybrid vigour in F_1 generation of glasshouse tomatoes. The purpose is to find the most suitable varieties to use as parents to give earliness, quality, and disease resistance. For the 1950-51 season, there were no significant yield differences between the crosses and the highest-yielding parent, and no F_1 cross had a significantly higher yield than the variety commonly grown in the district, namely, South Australian Dwarf. There was evidence, however, that some F_1 crosses had higher early yield than South Australian Dwarf. For the 1951-52 season, different varieties were used as parents and some evidence has been found of a degree of resistance to leaf mould in the F_1 cross, South Australian Dwarf x Vetomould.

For field tomatoes, progress has been made towards the development of hybrids suitable for Murray Valley areas combining resistance to Fusarium wilt with desirable agronomic qualities, especially bush habit. Single plant selections for several promising lines were made during last season; these are being tested for resistance to Fusarium wilt by the Division of Plant Industry.

There are encouraging prospects of developing a tomato variety resistant to root-knot nematode, one of the major problems of vegetable production in the region. Investigations have been made since the 1949-50 season in association with the Division of Plant Industry. Seeds of the resistant H.E.S. varieties 3963, 4103, 4108, and 4242 were obtained from the United States of America. These varieties have been crossed with several popular local varieties. F_2 generation plants were raised in nematode-infested soil at Red Cliffs, and about 100 plants showing resistance were planted into the field for single plant selection for agronomic qualities.

A replicated trial of the effect of methods of farm management on the root-knot nematode population in the soil was commenced last season at Red Cliffs. The methods of management are (*a*) growth of susceptible tomato crop, (*b*) growth of resistant tomato crop, (c) clean fallow, and (*d*) summer fallow, followed by autumn-sown barley. Among methods being tried to assess the changes in root-knot nematode population under the different systems of land management are the counting of larvae in roots of young tomato plants grown in the glasshouse in soil samples taken from the various land treatments and the rating of mature tomato plants, grown similarly, for severity of root-gall formation due to root-knot nematode.

3. Irrigation Research Station (Murrumbidgee Irrigation Areas), Griffith, New South Wales.

The work of the Research Station at Griffith is concerned with irrigation and drainage problems and related soil problems; studies of plant physiological and horiticultural problems associated with the production of the district are also included.

(*a*) *Irrigation.*—The effect of soil moisture and weather on the rate of removal of water from the soil by plants in the field is being investigated by direct soil sampling. It is found that there is an approximately linear relation between the amount of water withdrawn from the soil per unit of evaporation and the soil moisture content. The slope of the water extraction-soil moisture curve depends on the type of crop and probably also on the soil type. A knowledge of the effect of weather and soil conditions on water use by crop is helpful in the practice of irrigation and is required in designing irrigation projects.

(*b*) *Drainage.*—The waterlogging and salting of soils in semi-arid and arid regions, which often results from irrigation, is widespread on the Murrumbidgee Irrigation Areas.

Drainage studies have been continued on another major soil type and it was found that the soil showed an appreciable response to drainage at the 8-ft. level. Over the past few years data obtained from these studies have been applied on four private farms where tile drainage systems have been installed. On these farms the tile drainage systems have controlled the water-table and removed surface salting.

Further data were collected from the first farm-size tile-drainage trial during the year. Considerable quantities of excess water and soluble salts were removed. Data were also obtained from the second farm-size tile-drainage trial that was installed just before the irrigation season began. On this second trial it is possible to compare drained and undrained sections, and the value of the tile-drainage system was indicated by the water-table levels. On the drained plots the water-table level had been reduced to 46 inches below the surface, although on the undrained area it was only 16 inches from the surface.

The movement of soluble salts is being studied by means of radio-sodium. Problems encountered included the quantitative recovery of the isotope, but a method giving full recovery has been worked out. Quantities of isotope in excess of 1 mc. are needed, as dissipation under field conditions is great.

(*c*) *Chemistry.*—The effect of various treatments on the exchangeable cations of the soil are being studied. Applications of ammonium sulphate to the soil cause a drop in the exchangeable calcium and magnesium and an increase in the exchangeable hydrogen and manganese, and appears to reduce the exchange capacity of the soil. This last effect is more pronounced in sandy than in heavier soils. Heavy irrigation caused an increase in the exchangeable manganese.

(*d*) *Soil Physics.*—In irrigation farming there is a danger of deterioration in soil structure. Aggregate stability may be reduced and the soil may become puddled, with loss of permeability to water. The three major causes of this structure deterioration, namely, unfavorable salts in the soil water, mechanical compression by faulty cultivation practices, and loss of organic matter, are being investigated.

A new method of determining the structural behaviour of a soil to saline irrigation water has been developed. The permeability of fine calcium-saturated aggregates to various solutions of sodium and calcium chlorides is measured by means of a micropermeameter. Photographs of the aggregates taken through the glass side of the permeameter show that the decrease in permeability caused by solutions with a high sodium: calcium ratio is due to the increased swelling of the aggregates. Where pure sodium chloride solutions are used the aggregates swell to the extent that there is a complete collapse of the pore system.

The susceptibility of the soil to mechanical puddling is measured by means of a soil shear and compression machine. Present results indicate that soil reconditioning treatments, such as five years of lucerne or pasture, which have a big effect on soil aggregation as compared to five years of vegetable culture, do not have a sensible effect on the susceptibility of the soil to mechanical compression.

In the experiment on the effect of cultural treatments on citrus, reported in Sub-section (*e*)(i). It was found that, although there is very little difference in the amount of organic matter in the soil of the different plots, the aggregation is much lower in tilled than in untilled plots. Increased ammonium sulphate applications tend to give higher aggregation values both on the sod and the bare soil plots. In the tilled plots applications of farmyard manure at the rate of 3 tons/acre per annum have no significant effect on either the soil organic matter content or soil aggregation.

It was found that the infiltration rate in the sod plots was about three times that in the bare plots, although the apparent density and the non-capillary porosity in the sod plots is slightly lower than in the latter. The number of insect burrows in the sod plots is five times the number in the bare plots and it is assumed that a large part of the pore system consists of these burrows, giving rise to very high infiltration rates.

Records of soil temperature at depths from ½ inch to 8 feet over a period of eight years have been analysed. The data fit the theoretical equation for a simple sine wave applied at the surface propagated into a medium of uniform diffusivity.

(*e*) *Horticulture.*—(i) *Factorial Field Experiment with Citrus.*—The factorial field experiment with citrus previously reported is showing interesting results. The tendency for the bare soil trees (untilled, weeds controlled by oil spray) to give greater yields of fruit than the other treatments remained. In this treatment, although the different nitrogen levels 0, 4, 8, and 16 lb. ammonium sulphate/acre have not caused differences in health or yield, the appearance of the trees receiving no nitrogen suggests that they may now be experiencing a nitrogen stress. In the sod plots those trees with 0 and 4 lb. of ammonium sulphate have declined further in health. The irrigation treatments continue to cause no differences in tree health, size or yield.

Manganese deficiency has appeared in the trees and a visual and chemical survey, in progress, indicates that the deficiency is more severe in the orange root-stocks than the rough lemon and under heavy irrigation than under light. There is less manganese in the leaves of the non-cultivated than in the cultivated treatments.

Soil nitrogen studies in this experiment have continued with a field survey of the amount of ammonia and nitrate in the soil after the half-yearly addition of ammonium sulphate fertilizer. Results so far show that the soluble ammonia disappears rapidly in the sod culture treatment compared to the slow rate in the bare soil plots. The rate of disappearance in the two cultivated treatments is midway between the first two mentioned. These results are in line with a laboratory pot experiment.

(ii) *Red Scale.*—A method of removing red scale from oranges after harvesting was evolved. After fumigation with hydrocyanic acid the fruit is passed through a descaling bath and the dead scales brushed off.

(iii) *Frost Protection.*—Whilst the Section of Meteorological Physics (*see* Chapter XXVII., Section 5) continued with trials of the low-speed fan, the Station continued with the high-speed horizontal axis fan. Readings taken in the orchard indicate a useful temperature control but the effect cannot be accurately determined until a really damaging frost occurs.

(*f*) *Plant Physiology.*—(i) *Soil Fertility.*—Investigations are continuing on the effect on the growth of plants of adding organic matter, such as rice hulls, to the soil. Three distinct types of response are now recognized, an adverse effect on germination, a set-back to seedling growth, and a subsequent stimulation of growth such that the final yield exceeds that of the control. The subsequent stimulation in growth is due to an increased intake of phosphorus. The evidence so far favours the view that the additional phosphorus is liberated from the soil and is not derived from the added organic matter. As a first step toward establishment of this point a pot culture study of the interaction of rice hulls and the relatively insoluble phosphates of calcium, iron, and aluminium has been completed. With ferric phosphate in particular the presence of both rice hulls and the phosphate greatly increased the intake of phosphorus by tomato seedlings.

(ii) *Plant Water Relations.*—The effect of wilting on the growth and nutrition of plants is being studied. It was found that wilting caused a decrease in the relative growth rate of tomato plants which was followed by an increase in this rate when the plants were watered. The wilting caused a decrease in the absorption of nitrogen and phosphorus, but, on watering, increased amounts of nitrogen and phosphorus were absorbed leading to higher percentages in the wilted plants.

V. ANIMAL HEALTH AND PRODUCTION.

1. General.

The importance of animal husbandry to the economy of Australia is reflected in the extensive field of research undertaken by the Division of Animal Health and Production, which is reported in this Chapter and in Chapters VII. and VIII.

The nature of the problems varies greatly and many branches of science make their contribution to new knowledge which is required for their solution. The infectious diseases of livestock do not now cause the wastage which was common in the past, so that more attention can now be given to other causes of loss of production.

Co-operative work with other Divisions and with Departments of Agriculture and the universities in the several States and Federal Territories has continued to play an important part in the activities of the Division.

2. Animal Health Research Laboratory, Melbourne.

This is the administrative head-quarters of the Division. Experimental work is carried out in this laboratory on problems of animal physiology and pathology. The work relating to sheep is reported in Chapter VII. and that relating to cattle in Chapter VIII.

(*a*) *Microbiological Chemistry.*—Study of the pleuropneumonia organism has shown that its growth requirements are complex and that serum has more than one function in culture media; besides supplying one or more growth factors, it appears to be necessary to neutralize certain growth inhibitors or toxic substances present in some media. Considerable progress has been made in the study of the metabolism of the organism. Much attention was given to the role of carbon dioxide in its nutrition.

3. McMaster Animal Health Laboratory, Sydney.

The work in this laboratory includes the study of internal and external parasites and parasite toxicology, nutrition, and the physiology of reproduction. That relating to sheep is reported in Chapter VII. and that relating to cattle in Chapter VIII.

Interesting results have been obtained during the year from work carried out in collaboration with the Chemistry Department of the University of Sydney concerning the mode of action of phenothiazine and the biological activity of complex ions (Chapter VII., Section 16).

(*a*) *Section of Mathematical Statistics.*—The officers of this Section who are attached to the Division are housed at the McMaster Laboratory. They have continued to play an active and most valuable part in the planning of experiments and in the analysis and interpretation of results. The officer in charge of this work is a member of several of the research teams, including those conducting the sheep-breeding trials and the strain trials within the Division. The results of some of the work are incorporated in Chapter VII., Section 13 (*c*).

4. VETERINARY PARASITOLOGY LABORATORY, YEERONGPILLY, QUEENSLAND.

The Veterinary Parasitology Laboratory of the Division was established at Yeerongpilly, Brisbane, in 1948, to undertake investigations into parasites affecting livestock, particularly those of importance in Queensland. The laboratory also accommodates officers of the Division of Entomology who are engaged in investigations into the bionomics and control of the cattle tick.

Close co-operation with the State Department of Agriculture and Stock is maintained and is assisted by the Joint Veterinary Parasitology Committee.

Investigations in progress include the following studies. Other investigations are reported in Chapter VIII., Section 3.

(*a*) *Allergic Dermatitis (" Queensland Itch ") of the Horse.*—Studies on " Queensland Itch " are almost completed. This disease has been shown to be an allergic reaction to the bites of a sandfly, a new species of *Culicoides*. The initial skin lesions, consisting of discrete papules, are associated with the liberation of histamine in sensitized animals. When the lesions are active there is an increase in the concentration of blood-plasma histamine which is free to exert its action on the tissues and cause intense itching. The histamine is thought to be liberated by the action of an antigen—the salivary secretion of the sandfly—and antibody attached to sensitized tissue cells.

In sensitized animals there is a temporary increase lasting from 30 to 60 minutes in both total blood histamine and plasma histamine after intradermal injection of antigen or after the bite of a sandfly. It was also demonstrated that the blood of sensitized animals contains a skin-sensitizing antibody and that this is responsible for the positive passive transfer of sensitivity to non-sensitized horses and guinea pigs.

Sensitized animals were injected intradermally with antigen or histamine and microscopic examination of their skin revealed in both cases histological changes identical with those seen in the early stages of the disease. When either antigen or histamine was injected into non-sensitized or immune animals a similar histological picture was seen only with histamine. The cellular reaction in non-sensitized animals was not as extensive as that seen in sensitized animals. Susceptible animals were protected when sprayed weekly with 1 or 2 per cent. DDT.

(*b*) *Tick Toxins.*—Investigations have shown that there is apparently little difference in the toxicity of the eggs of *Boophilus microplus, Haemaphysalis bispinosa, Ixodes holocyclus, Amblyomma triguttatum*, and *Rhipicephalus sanguineus.* Approximately 0.2 g. of eggs inoculated subcutaneously caused the death of a 700 g. guinea pig in 24-96 hours. Smaller doses, 0.05 g., caused a local thickening at the site of injection and subsequent loss of hair. Electrophoresis patterns of an aqueous extract of the eggs of *B. microplus* gave at least four components, the major portion belonging to α-globulin. Toxicity tests indicated that the globulin separated by half saturation with ammonium sulphate was the more toxic fraction.

(*c*) *Tick Taxonomy.*—Following a revision of the genus *Aponomma*, studies were extended to the Australian species of the genus *Amblyomma*, which is occasionally seen on domesticated animals. Twelve species of *Amblyomma* were recognized in the material examined, including four new species. This work has been prepared for publication. Also, some time has been devoted to identification of specimens for the Queensland Institute for Medical Research.

5. F. D. MCMASTER FIELD STATION, BADGERY'S CREEK NEW SOUTH WALES.

The work of the Station has been largely the development and study of hybrid dairy cattle based on Zebu crosses with British breeds. The breeding studies on sheep have also been continued.

The hybrid cattle study is reported in Chapter VIII. Section 5, and the sheep-breeding studies in Chapter VII., Section 13.

6. WOOL BIOLOGY LABORATORY, SYDNEY.

(*a*) *Comparative Studies of Breeds of Sheep.*—This investigation, which has been in progress for several years, is now completed and is in the final stages of analysis for publication as several papers.

(*b*) *Experimental Histology of Skin and Hair.*—The project, referred to in the last Annual Report, of applying the tissue culture technique to sheep skin, has succeeded and a study is now in progress of the nutritional requirements for hair growth in culture, the role of dermis and epidermis in follicle and hair fibre formation, and the dynamics of the hair follicle population in sheep.

(*c*) *Other Investigations.*—Other work of this Laboratory is described in Chapter VII., Section 14.

7. REGIONAL PASTORAL LABORATORY, ARMIDALE, NEW SOUTH WALES.

Excellent facilities have been developed on the " Chiswick " Field Station, which is one of the areas used for the study of strains of sheep in several environments reported in Chapter VII., Section 13 (*d*).

The study of the effects of grazing management on pasture and animal production, which is a co-operative investigation with the Division of Plant Industry, is reported in Chapter III., Section 17 (*b*), and Chapter VII., Section 19 (*b*).

Work on the internal parasites of sheep and cattle is reported in Chapter VII., Section 16, and Chapter VIII., Section 3 (*a*), respectively.

Other investigations include the following:—

(*a*) *Studies on Animal Behaviour.*—Observations made specifically to measure whether grazing behaviour of sheep varies seasonally are being undertaken on the size-of-flock trial. These must be continued for some time yet to cover the range of seasonal conditions. Grazing intensity over a 7½ acre paddock grazed for one week in four has been observed to vary. The sheep show a preference for certain parts of the paddock and this preference has been measured by recording the presence or absence of fresh dung (not more than one week old), in randomly placed observational units located in each square of a grid which covers the paddock. Three observations, in March, April, and May, 1952, have produced similar grazing patterns.

(*b*) *" Staggers " in Sheep.*—A further outbreak of " staggers " occurred during 1951 in young sheep grazing a phalaris-clover pasture growing on a granitic sand. In investigations extending over two years, micro-nutrients have been used as a top-dressing for the pasture in an effort to prevent the disease. Applications of zinc, boron, and copper have not been successful. However, no cases of staggers have developed on a pasture top-dressed with cobalt in combination with other nutrients, and in view of South Australian experience, it is probable that cobalt gave protection from the disease in this instance. Current trials are designed to test the effectiveness of cobalt in preventing the disease under New England conditions. The cobalt is being administered to the grazing sheep by mouth and has also been applied to the pasture as a top-dressing.

(*c*) *Production from Sown Pastures* versus *Native Pastures*.—In a comparison of liveweights and wool production from two groups of Merino sheep of the same age and breeding, a marked advantage in favour of grazing phalaris-subterranean clover pasture, compared with a native redgrass (*Bothriochloa ambigua*) pasture, has been recorded. At the beginning of September, 1951, the mean weights of the two groups were 94.2 and 52.5 lb. for the sown and native pastures respectively. At shearing in October, the weights of greasy wool cut per head were 9.9 and 5.4 lb. As the rates of stocking were 3 sheep/acre and 1 sheep/acre for the sown and native pastures respectively, the use of the phalaris-clover pasture gave a 5.5-fold increase in return of wool per acre.

8. National Field Station, "Gilruth Plains", Queensland.

From July to November, no effective falls of rain occurred. The falls in December, February, March, and April were above average, but January was dry. Until late in December pastures deteriorated. Mitchell grass responded well to the December rains but the grass was "burnt off" by the hot and dry conditions in January. There was an impressive response to the low rainfall of 2.61 in. in February and 2.09 in. in March by Mitchell grass (*Astrebla* spp.) and blue grass (*Dichanthium sericeum*), and by germination of annuals.

Because of conservative stocking rates the breeding ewes were maintained in reasonable condition. The weaners responded well to the flush of growth in the pastures after the rains in February, March, and April. The mortality rate in lambs between marking and weaning continued to be high. It is believed that predatory animals were mainly responsible. The wool produced during the 1951-52 season was attractive, evenly grown, and suffered little from weather and other disturbing effects. Tender fleeces were almost completely absent. Nevertheless, production rates were not high. The maiden ewes produced 8.79 lb. of greasy wool per head, the 1948 drop produced 8.68 lb., and the 1947 drop 8.88 lb. The older ewe drops, 1942-44, produced 6.25-6.65 lb. The number of lambs weaned from the maiden ewes was low at 45.6 per cent. as was the number from the nine-year-old ewes at 48.8 per cent. The mean for the other groups was 68.3 per cent.

Work on the sheep-breeding projects progressed during the year. Another project, a study of the inheritance of horns in sheep, was commenced. As the lamb-marking percentages have been low, progress has not been so rapid or so satisfactory as desired. Efforts were made to improve the technique of sampling the fleece and measuring the body. In the major project, studies were continued on breeding systems and on inheritance of characters with 28 sire groups (*see* Chapter VII., Section 13). Investigations were also continued with the second project, the "strain trials", in which five selected strains of Merino sheep are being studied in three distinct environments of which that at the Field Station is one (*see* Chapter VII., Section 13).

Investigations into lamb mortality have continued. Three experimental flocks were kept under close observation. The 1,352 ewes dropped 1,183 lambs of which 865 were present at marking. The loss in lambs between birth and marking was 26 per cent. Of this loss, 18 per cent. was within the first six days of life and 82 per cent. between seven and 30 days. The investigations indicate that the losses are largely due to the action of predatory animals including eaglehawks, foxes, crows, and kitehawks, and failure of the ewe to suckle the lamb either through low production of milk or through damaged or faulty udders. The loss with maiden ewes is due either to poor supply of milk or poor mothering instinct and with aged ewes to poor supply of milk.

9. Fleece Analysis Laboratory, Villawood, New South Wales.

The Laboratory carried out the large number of physical measurements on the fleece of sheep that were required in the experimental biological work of the Division of Animal Health and Production. During the year 23,412 measurements were made, including yield determination, density, mean diameter, staple length, and crimp. The techniques for the measurement of diameter and density remained unchanged. An economy of about 50 per cent. in the use of detergents and in electric power for the large scour was effected. Some modifications to the solvent scour procedure were also made. For the Wool Biology Section, measurement of the mean length of fibres in each of 278 clippings was made. This involved the measurement of 27,800 fibres which varied in length from about 0.4 to 2.0 cm. Difficulties were successfully overcome by mounting the fibres on a glass slide with translucent adhesive tape and measuring the projected image.

The main investigation during the year was on the transfer of heat and moisture in fibrous masses with a view to application in textile drying and in studies of climatic physiology of the sheep. Valuable results were obtained in determining "regain adjustment rate" curves for wool fibres in air streams and in developing a satisfactory technique for determining heat-transfer constants for air streams moving through fibrous masses.

Work was continued on the investigation of "handle" of wool but comparatively little progress was made in elucidating the reasons for the different grades of handle assigned to a number of pairs of samples having the same diameter.

10. Poultry Research Centre, Werribee, Victoria.

The experimental flock at the Poultry Research Centre has been increased considerably during the past twelve months. Stock figures taken on 1st June, 1952, indicate that the flock comprises 4,567 female and 692 male birds. The pullet flock, representing the F_4 generation, accounts for 58 per cent. of the laying flock, the number of pullets housed being 2,649. With the completion of trapnest house No. 6, accommodation has now been provided for 4,878 laying birds. A new incubation room has been erected, and, with the purchase of a 6,300 capacity multiple incubator, it is expected that the period for breeding can be considerably reduced, and thus the accuracy of partial records increased. The general research programme remains unaltered.

(*a*) *Investigation of Breeding Systems*.—Results from a detailed analysis of the E pullets (F_3 generation) are as follows:—(i) Crossbred pullets from the leghorn and Australorp breeds produced an average of 220 eggs over the period of measurement—some 32 eggs more than the better parent breed; (ii) the criss-cross breed, involving both Leghorns and Australorps, also produced very highly (219 eggs); (iii) excellent results were obtained from the "three-way" crosses (210 eggs), but mortality was higher than in any other group; (iv) with the exception of the Hagedoorn system, in which no progress has been made as yet, the systems of breeding involving progeny testing have yielded positive results; (v) phenotypic selection based on body conformation has been unsuccessful in maintaining production at a level even comparable with the control group of random matings—the group which results from the matings of sons of winners of egg-laying competitions with high producing dams is at present giving very good results, which seems to indicate that the cockerels used recently have been of particular genetic merit; and (vi) generally speaking, inbreeding has not had any deleterious effects on stock, although one family has succumbed to this treatment with degeneration in fertility, hatchability, and rearability. The average level of inbreeding of the B.A.I. group is in the vicinity of 50 per cent.

(*b*) *Physiology of Reproduction and Inheritance of Fecundity.*—The storage of semen by deep freezing is being investigated. With the use of a diluent of 40 per cent. glycerol in Ringer's solution, practically complete revival of sperm is obtained on thawing when ejaculates of good quality are used (motility being the criterion of determination). However, any percentage of glycerol that enables the sperm to resume motility after thawing renders the sperm completely incapable of effecting fertilization. This situation exists even if the sperm have not been frozen. A small percentage of fertility has been obtained by the intra-peritoneal method of insemination rather than by the more orthodox one via the oviduct. Removal of the glycerol from the sperm suspension by washing gives a small improvement in the fertility of unfrozen sperm. Slow removal of the glycerol by dialysis is at present being tested. Although fructose was found to be present in fowl semen and its addition to diluents improved motility of the sperm, normal fertility was obtained when semen was washed free of sugars. Deficiency of fructose in the seminal plasma is therefore not a likely cause of infertility in the male. With the object of storing sperm in an inactive condition at room temperature, it has been noticed that they can be reversibly immobilized with hypertonic saline and 0.75M glucose solution. Fertility of fowl ejaculates was reduced when immobilized sperm were inseminated but was considerably improved by restoring the sperm to motility before insemination.

11. Other Investigations.

(*a*) *Investigation of Beef Production in Australia.*—(i) *Survey of Beef Cattle Production.*—This survey has been completed. The information collected has been under critical examination for the preparation of reports. A report on beef cattle production in northern Australia was published and circulated during the year. A report for southern Australia is in course of publication.

(ii) *Co-operative Investigation of Growth of Beef Cattle on Pasture.*—Officers of the Departments of Agriculture of the southern States have undertaken an investigation of annual growth curves of beef cattle on pasture. Information is also being collected on supplementary feeding and carcass appraisal. The work has been assisted by funds provided by the Australian Meat Board. The Division of Animal Health and Production has assisted in the design of the investigation and in the collation of results. The work is proceeding.

(iii) *Feeding of Beef Cattle under Stud Conditions.*—Collection of nutritional information from one herd was discontinued temporarily, but complete records were collected from another for a third year.

(*b*) *Sparganosis in Pigs.*—Large numbers of spargana (the second intermediate stage of a diphyllobothrial tapeworm) were found in pigs that were originally running wild but were caught and fattened for slaughter. The infested tissues were fed to dogs and cats in which the parasites developed to maturity and were identified as *Diphyllobothrium erinacei.* Foxes in the vicinity were found to be infested with the adult parasite. The investigation has been continued by the School of Public Health and Tropical Medicine in collaboration with the Veterinary Research Station, Glenfield, of the New South Wales Department of Agriculture.

VI. NUTRITION.

1. General.

The Organization's work in the realm of general nutrition is largely devoted to studies of the nutritional physiology of ruminants and more especially to the nutrition of sheep and to the influence of nutrition on wool production, a field of knowledge of prime importance to Australia which has been inadequately explored.

The experimental investigations are conducted by the Division of Biochemistry and General Nutrition which has its head-quarters and laboratories in the grounds of the University of Adelaide, and has field stations at various sites in Australia where nutritional disabilities occur. Knowledge arising from the Division's experimental work is extended to application by the State Departments of Agriculture and other bodies, with whom there is a close liaison. This Chapter describes the main researches of the Division. Further details of the studies on various aspects of the nutrition of sheep are to be found in Chapter VII. In Chapter III. there is a report on the application of the latest findings arising from plant nutrition studies to the development of the Ninety-Mile Desert, South Australia, which, since the application of the earlier findings of the Division, is rapidly losing the characteristics which led to its original name and has been officially renamed Coonalpyn Downs. The transformation of the low mallee heath of this area to splendid pastures is a remarkable example of the application of scientific research.

2. Nutrition and Wool Production.

Experimental studies of nutritional factors which directly influence wool production are reported in Chapter VII., Section 2.

3. Studies of the Metabolic Processes of Sheep.

These studies, which aim at a more complete understanding of the biochemical and physiological processes by which the sheep deals with its fodder, are reported in Chapter VII., Sections 3 and 5 (*a*). During the year these studies have materially advanced knowledge and indicate the reasons for the considerable difference between the metabolic behaviour of ruminant and non-ruminant animals. The recognition and treatment of many disorders of our flocks and herds may depend primarily on the understanding of these processes.

4. Energy Metabolism.

A sound knowledge of the overall utilization of energy by animals and of the efficiency with which various foodstuffs provide fuel to support living processes is fundamental to a correct appreciation of all nutritional problems. An important part of the Division's activities is devoted to animal calorimetry and to experiments associated directly with the energy metabolism of sheep. The considerable advances made in this sphere have served to clarify fundamental knowledge of energy transactions in all animals and have provided a sound basis upon which rations for the drought-feeding of sheep may be based (*see* Chapter VII., Section 4).

5. Vitamin A Requirements of the Sheep.

A comprehensive study of the vitamin A requirements of the sheep is being made. A shortage of this accessory food factor is the most likely vitamin deficiency to be suffered by sheep grazing for long periods on dry pastures (*see* Chapter VII., Section 8).

6. EFFECTS OF CHRONIC FLUOROSIS.

The studies of disabilities imposed on sheep confined to waters containing abnormally high concentrations of fluorine have been extended (*see* Chapter VII., Section 10).

7. BIOCHEMICAL AND NUTRITIONAL STUDIES OF MINOR ELEMENT DEFICIENCIES IN ANIMALS AND PLANTS.

To understand more readily the problems encountered in areas where productivity is limited by the small quantities of copper, zinc, &c., available from the soils, a comprehensive series of nutritional biochemical, and physiological studies of copper, cobalt, and zinc metabolism has been undertaken. Both copper and zinc are essential nutrient elements for plants and animals, and, apart from specialized physiological processes associated with their absorption, storage, and utilization, it is probable that the metabolic processes served by these elements are very similar, if not identical, both in plants and in animals. Thus animals as well as plants are used as experimental subjects in these studies, one or other being selected as convenience or simplicity demands. The series of studies of copper and cobalt deficiencies with sheep are referred to in Chapter VII., Section 11.

(*a*) *Copper Deficiency in Rats and the Effects of Molybdenum on Copper Metabolism.*—Nutritional and biochemical studies of copper deficiency in rats, which have served to solve problems associated with copper deficiency in sheep and with the effects of molybdenum thereon, have been completed and are in course of publication.

(*b*) *Zinc Deficiency in Rats.*—The difficult technical task of freeing foodstuffs from zinc has been accomplished and diets have been compounded which provide all essential dietary factors except zinc, the intake of which has been reduced to $<1\ \mu g.Zn/day$. Nutritional studies with these diets have proved that young rats need more than 20 μg. Zn/day for normal growth. Without supplements of zinc the growth of rats on these diets ceases abruptly, and the animals remain dwarfed but apparently in normal health, until their integument breaks down. With extra zinc, growth is proportional to the amount of zinc provided, up to approximately the full nutritional requirement. It is already clear that the animal organism has little capacity to store zinc, and has a remarkable ability to retain it. A study is being made of the carbohydrate metabolism of zinc-deficient rats as experiments (*see* below) have indicated that the carbohydrate metabolism of plants is seriously upset in zinc deficiency.

(*c*) *Metabolic Defects in Zinc-Deficient Animals.*—A series of biochemical studies of enzyme systems that are apparently affected in zinc deficiency has been undertaken. In seriously zinc-deficient rats the only metabolic defect that has been discernible after a comprehensive and critical study of the aldolase activity in the tissues is a slightly lowered activity of this enzyme in the brain. All tissues, when compared, w/w, with those from rats receiving adequate zinc and which were growing normally, contained closely similar concentrations of zinc. The activity of carbonic anhydrase in the blood of rats which were *in extremis* during the terminal stage of zinc deficiency was not appreciably lowered.

A study of the metabolic chain of events concerned with glycolysis in the tissues is being made with sections of diaphragm muscle, and the overall carbohydrate metabolism of zinc-deficient animals is being investigated.

(*d*) *Metabolic Defects in Zinc-Deficient Plants.*—Studies of the metabolism of zinc-deficient plants are being continued. Previous reports have indicated the findings which are now in the course of publication.

8. VITAMIN B_{12}.

(*a*) *General.*—A series of experiments aimed to illuminate various aspects of the nutritional physiology of the cobalt-containing vitamin B_{12} have been undertaken by the Division. Those concerned with sheep are mentioned in Chapter VII., Section 11.

(*b*) *Microbiological Estimation of Vitamin B_{12}.*—Microbiological means for the estimation of vitamin B_{12} have been modified for use in a number of investigations that are proceeding in the Division. Existing methods utilizing *Lactobacillus leichmannii* and a methionine-requiring mutant of *Escherichia coli* have been adapted for this purpose. These methods have been employed to study relationships between the cobalt content of the ingesta and the bacterial synthesis of vitamin B_{12} and of vitamin B_{12}-like substances in the alimentary tract of sheep.

(*c*) *Vitamin B_{12} Requirements of the Rat and Vitamin B_{12} Assays.*—A study is being made of the utilization of vitamin B_{12} by rats and of the physiological effects which supervene when the intake of the vitamin is limited to very small amounts. Vitamin B_{12}-free rations, that are otherwise adequate to support maximal growth, have been evolved. Critical direct methods suitable for the biological assay of vitamin B_{12} in foodstuffs, &c., are being sought. The function of vitamin B_{12} in the metabolic processes which deal with single-carbon atom fragments, and the function of vitamin B_{12} in the production and transfer of methyl groups within the tissues, are being studied to illuminate further the role of this vitamin in the metabolism of animals. The rate at which animals become depleted of vitamin B_{12} and the influence of vitamin B_{12}-deficiency on pregnancy and on the rate of growth of the offspring are being investigated.

(*d*) *Vitamin B_{12} and Haemopoiesis.*—The effect of vitamin B_{12} on the formation of protoporphyrin, the highly methylated intermediary metabolic product of haematin, is being studied as part of a more comprehensive study of the function of vitamin B_{12} in the production of red blood cells.

9. PLANT NUTRITION.

The studies on mineral nutrition, which led to the development of the Ninety-Mile Plain, are being continued to investigate a number of specific problems associated with particular soil types in that region. The field work is being supplemented by nutritional and physiological studies of zinc and of copper deficiency in plants grown under controlled glass-house conditions in culture solutions and in deficient soils. This is referred to in more detail in Chapter III.

10. ISOTOPIC TRACERS.

The radioactive isotopes C^{14} and Co^{60} and the heavy isotope of nitrogen, N^{15}, are being employed as tools of research in several of the problems reported above.

11. FIELD STATIONS.

(*a*) *Glenthorne.*—Several of the experiments mentioned in Chapter VII. have been undertaken at the Division's central field station at O'Halloran Hill about 11 miles from Divisional head-quarters. The main flocks, about 1,100 strong-woolled and fine-woolled sheep from which the Division selects most of its experimental animals, are depastured there, and special foodstuffs, &c., for pen-feeding experiments, &c., are produced at this station. In addition to experiments mentioned elsewhere, a series of studies which aim broadly to investigate some outstanding problems associated with meat production have been initiated during the year. The first of these, on the relative values of meat meal and whale solubles as protein supplements for bacon production, is a direct trial which is being conducted in collaboration with the South Australian Department of Agriculture. These experiments aim to establish feeding standards which will conserve protein concentrates, the supply of which is likely always to limit the amount of pig-meat and of eggs that can be produced.

VII. SHEEP.

1. General.

The Organization's work for the pastoral industry described in this Chapter includes that of the Division of Animal Health and Production, reported in Sections 3 (*f*), 5 (*b*), 6, 7, 12-17, 18 (*a*), and 19; of the Division of Biochemistry and General Nutrition reported in Sections 2, 3 (*a*)-(*e*), 4, 5 (*a*), and 8-11; and work of the Division of Entomology on the sheep blowfly is reported in Section 18 (*b*)-(*c*).

The Section of Mathematical Statistics is closely associated with the breeding investigations, described in Section 13, both in the design of experiments and the analysis of results.

Work on soils and pasture improvement included in Chapters II. and III. is also of value to the pastoral industry.

Work on wool utilization is described in Chapter XV.

2. Nutrition and Wool Production.

A series of experiments conducted by the Division of Biochemistry and General Nutrition has revealed the nutritional factors which determine the rate of wool production, and has stressed that two variables are mainly concerned, namely, the quantity and quality of the protein consumed by the animal, and the net energy available from the rations. Experiments have been extended during the year to determine precisely the extent of change in the efficiency of utilization of protein for wool production which supervenes when the amount of fuel available to the animal is limited. Observations of the rate of wool production in animals, whose energy and nitrogen balances were determined precisely, have enabled an accurate determination to be made of the effects of the energy status of the animal on the efficiency with which different levels of protein in the fodder are utilized for wool production. These effects are large. The results are being published in the series of papers which deal with the physiology of wool production.

These studies show clearly why merino sheep grazing on natural pastures rarely exhibit their full propensity to grow wool. It was stressed in previous Annual Reports that the great seasonal changes in the rate of wool production by grazing sheep are not due simply to alterations in the protein concentration of the available fodder, but are a reflection of changes in the quantity and overall nutritive quality of the pastures. The rate of wool growth is certainly influenced profoundly by the intake of protein, but the efficiency with which protein is utilized by the sheep is determined primarily by the intake of carbohydrates, &c., which serve as fuel to meet the animal's energy requirements.

Unless the sheep is able to procure sufficient fodder to meet its energy requirements, provision of protein concentrates in the hope of increasing wool production would be folly, for, when the intake of other foodstuffs is insufficient, the major proportion of the expensive supplement would be utilized for energy production by the animal and the overall capacity of the supplement to provide a substrate for wool production would be decreased to such a low level as to render supplementary feeding no longer economically feasible.

These studies have rendered it possible to define more precisely the circumstances under which supplementary feeding for wool production may be expected to yield economic returns, and, *inter alia*, have shown clearly that the attempts which have been made to assess the wool-growing propensity of individual sheep from consideration only of the protein intake are untenable.

3. Processes of Rumination.

(*a*) *Formation of Volatile Fatty Acids in the Fermentation of Cellulose, Hemicellulose, and Protein by Micro-organisms from the Rumen.*—Further studies on the products of fermentation produced in the sheep's paunch have been conducted by the Division of Biochemistry and General Nutrition.

In vitro fermentations of cellulose and of hemicellulose isolated from wheaten hay have both been found to give rise to approximately equal parts of acetic and propionic acids together with a very small proportion of butyric acid. The addition of protein to the fermentations leads to an increase in the proportion of butyric acid formed. A paper has been submitted for publication.

(*b*) *Bacteriology of the Rumen.*—Studies on the micro-organisms responsible for the fermentation of carbohydrates in the rumen have been extended.

(i) An organism very similar in its morphology to *Clostridium kluyveri* has been isolated from rumen fluid. This organism produces butyric acid when grown in a medium containing acetic acid and ethyl alcohol. The importance of this organism in the rumen is indicated by dilution counts which show the presence of 1-2 million/ml. of the rumen fluid obtained from sheep on normal rations.

(ii) Work has been started on the isolation of rumen bacteria capable of breaking down hemicellulose. Several organisms have been shown to grow on hemicellulose media and to be present to the extent of two or more millions per ml. of rumen fluid. Isolation of these organisms is proceeding.

(*c*) *Passage of Starch from the Rumen to the Abomasum.*—The first stages of this experimental work, which is part of a comprehensive study of the digestive tract of the sheep, has now been completed. Starch-lignin ratios have been determined during 24-hour periods in the rumen and abomasum of a sheep fed on diets both low and high in starch. The data allow computation of the amounts of starch passing to the abomasum under these conditions. Experiments are now being planned to check the findings by an alternative method. This work is also related closely to that referred to in Sub-section (*d*).

(*d*) *Passage of Fatty Acids from the Rumen to the Abomasum.*—Determinations have been made of the fatty acid contents of rumen, omasal, and abomasal fluids and of fluctuations of the fatty acid concentration in the abomasum throughout 24-hour periods. The effect of intermittent addition of fatty acid to the abomasum, on fatty acid concentration in that organ, has been studied.

This work, and that referred to in Sub-section (*c*) above, are parts of a study of the physiology of absorption in the intestinal tract of the sheep, which is designed to throw light on the passage of solids and liquids, and also of the fatty acids themselves, from the rumen to the abomasum; this knowledge is very important for an understanding of the mechanics of rumination.

(*e*) *Utilization of Urea.*—Experiments on the utilization of urea as a 'protein concentrate' for sheep have been completed. The general findings indicated that the micro-organisms in the rumen will convert a considerable quantity of urea to protein, which is well utilized by the animal, provided a considerable amount of an easily accessible carbohydrate, such as starch (grain) or molasses, accompanies the urea. The effectiveness of the urea-starch supplements was measured in terms of enhanced wool growth, and the results indicated that the use of such supplements might be economically feasible in areas where the quality of available fodder is sufficient to meet the energy demands of the grazing animals but where the deficiency of protein in the dry pastures seriously limits wool growth. The usefulness of such supplements should be tested by experiments conducted under conditions of station practice. To this end experimental trials have been commenced in collaboration with the Queensland Department of Agriculture and Stock at their Toorak Field Station, Julia Creek, north-west Queensland.

(*f*) *Ruminal Digestion.*—The main findings from work carried out on this subject during the year at the McMaster Animal Health Laboratory are as follows:—pH, which is a principal factor in controlling the course of ruminal digestion, is inversely related to the level of volatile fatty acids and is depressed to a still greater extent when lactic acid accumulates in the rumen; appreciable amounts of lactic acid, such as may occur when there is a sudden increase in the consumption of concentrate rations which contain much available carbohydrate, grossly affect digestion, and cause partial or complete loss of appetite and inhibition of microbial growth with consequent reduction in the rate of digestion of cellulose and deamination of proteins. The accumulation of lactic acid appears to be inhibited by the addition of ground limestone to certain rations; considerable practical advantage can probably be taken of this finding. The ammonia produced in the rumen from high protein diets is not efficiently utilized unless the ration is also rich in available carbohydrate. These findings have considerable practical significance. They offer a possible explanation of the digestive disturbance and loss of appetite which may occur when ruminants are highly fed on some concentrate rations and stress the importance of a proper balance between the protein and available carbohydrate contents of the feed, if ruminants are to make full productive use of their rations. Lucerne hay, for example, a most valuable feed if properly used, is unbalanced and therefore wasteful, if fed alone because it contains too little available carbohydrate to support a ruminal flora which can fully utilize the ammonia produced from its high protein content.

The use of polyvinyl alcohol as an inert "marker" in digestive studies on ruminants is being investigated, but some difficulties have yet to be overcome.

4. ENERGY METABOLISM.

The laboratory of the Division of Biochemistry and General Nutrition is one of very few in the world that are at present devoting attention to the overall energy metabolism of homeothermic animals. During the year a series of complete energy-balances conducted on a number of sheep confined to rations of dried lucerne have amply confirmed the predictions made previously by the Division from similar experiments with other diets, and have established a fundamental law of energy metabolism, namely, that the extra heat production which occurs on feeding is linearly related to the amount of combustible energy in the digestion products that are absorbed. In other words, a constant proportion of the energy in the rations is dissipated as heat without apparently serving any useful purpose, irrespective of the level at which the ration is fed. The corollary, which would imply that the proportion of energy dissipated in this way would differ with the nature of the ration, has also been proved. These laws hold when the rations provide sufficient energy to establish a positive energy balance in the animal. A study of the dissipation of energy in sheep subsisting on sub-maintenance rations is being conducted in the Division as a part of its drought-feeding programme. The information obtained in these experiments is necessary to form a sound basis for the hand feeding of flocks during drought, and it is also fundamental to the understanding of the nutrition of all animals.

5. CARBOHYDRATE METABOLISM.

(*a*) *Intermediary Metabolism.*—Studies of the intermediary metabolism of carbohydrates in the sheep have been continued. As a lead to a more complete understanding of the reasons for the remarkable differences between the metabolic behaviour of ruminants and that of other animals, the effect of insulin on young and on mature ruminants has been given considerable attention. The findings stress the difference between the carbohydrate metabolism of the newly born lamb and that of the adult sheep. Carbohydrates are dealt with by the lamb in a way which is closely similar to that of non-ruminant animals, whereas, in the adult sheep, alternative metabolic pathways have seemingly developed to a novel extent. And this is reflected in the reaction towards insulin. In the newly born lamb, moderate doses of insulin (4U./kg.) were observed to produce severe hypoglycaemia and concomitant convulsions which were relieved when extra glucose was administered. In the adult sheep, massive amounts of insulin were required to reduce the blood sugar to a level comparable to that at which convulsions ensued in lambs; at this level the adult never convulsed. Denervation of the adrenal glands by section of the splanchnic nerves was observed to render both lambs and adult sheep more sensitive to insulin but it did not lessen the great difference between their reactions. Propionic and butyric acids were found to be effective in relieving the hypoglycaemic convulsions induced by insulin; these fatty acids had been shown earlier in the studies to be readily converted to glucose in the sheep.

Work on alloxan-induced diabetes has been extended to studies of the efficiency with which the animals deal with the products of fat metabolism. Ketonaemia was observed in both ewes and wethers that had been rendered diabetic by injection of alloxan; the wether, however, is apparently more prone to diabetic acidosis. The presence of fructose in the blood of newly born lambs has been confirmed by quantitative partition chromatography; estimates of fructose in the blood by this means agreed very closely with direct assays. The influence of alloxan-induced diabetes on the capacity of the sheep to acetylate sulphanilamide was investigagated; the findings suggest that the sheep's capacity to acetylate is less than that of the rat, and that a diabeic state does not decrease it further.

(*b*) *Carbohydrate Metabolism in Pregnancy.*—Detailed studies of carbohydrate metabolism on five ewes, during different periods of fasting in the last three weeks of pregnancy, gave results which are fundamentally different from those obtained during fasting in monogastric animals, or in non-pregnant sheep: the degree of ketonaemia was directly related to the degree of hypoglycaemia; glucose utilization by peripheral tissues may cease at blood-glucose levels below 15 mg./100 ml.; ketone bodies are not utilized by the peripheral tissues of fasted pregnant ewes, even when glucose is being utilized; when glucose utilization ceases, at low blood-glucose levels, β-hydroxybutyric acid is produced in, and eliminated from the peripheral tissues. The results suggest an active fat metabolism in peripheral tissues, similar to that which occurs in the liver. From these findings it may be postulated that, under the conditions of these experiments, there was a breakdown in the Krebs tricarboxylic acid cycle.

Further work is in hand which it is hoped will confirm and extend these findings. These investigations are providing a sounder basis for research on such diseases as pregnancy toxaemia of ewes and ketonaemia.

Detailed studies on glucose and volatile fatty acids in the blood of lambs have shown that the steady fall from high blood-glucose levels at birth to the much lower "adult" levels, within the first few weeks of extra-uterine life, is not related to the functional development of the rumen but to loss of glucose from the corpuscles of the blood.

6. Drought-feeding and Related Problems.

Experiments on the feeding of sheep, with particular reference to drought conditions, have been continued at Glenfield by the Division of Animal Health and Production in collaboration with the New South Wales Department of Agriculture. A substantial grant for this work was provided by the New South Wales Graziers' Association from the Burdekin Bequest. It is still in progress but some of the principal results obtained during the year are now described.

(*a*) *Comparison of Daily Feeding with Weekly or Twice-Weekly Feeding.*—These experiments were originally confined to adult wethers. They have now been extended to weaners and to ewes during pregnancy and lactation. Results throughout have supported the original finding that sheep fed at intervals up to a week thrive as well, or better, than those fed daily. The rations used were sufficient to maintain moderate to low store condition.

Many graziers in different parts of the Commonwealth have applied the results and have used weekly or twice-weekly feeding. For example, on a property near Willowtree, New South Wales, some 6,000 sheep were fed twice weekly with very satisfactory results throughout the late autumn and winter of 1951, when drought conditions prevailed.

(*b*) *Supplementation of Cereal Rations with Sodium Chloride.*—When 0.5 per cent. salt was added to 10 : 90 mixtures of wheaten chaff and wheat during drought-feeding experiments the rations were consumed more rapidly. When additional quantities of this ration were supplied to lactating ewes and growing lambs. the salt supplement resulted in the feeding being consumed more rapidly and in somewhat greater quantity, so that the lambs were very slightly heavier at weaning. This advantage, however, was not sufficient to justify the use of additional salt in drought rations, more especially as rapid consumption of the feed is then a definite disadvantage.

(*c*) *Drought Rations Comprised Solely of Wheat.*—Groups of weaners have been fed for seven months, at daily and weekly intervals, on wheat alone, except for the addition of finely ground limestone to balance the excess of phosphorus. These weaners thrived just as well as similar groups which received part of their ration as wheaten chaff, except that their vitamin A status declined more rapidly.

(*d*) *Vitamin A Requirements of Sheep under Drought Conditions.*—Mature ewes, with satisfactory vitamin A reserves, lambed and lactated satisfactorily when fed on a cereal diet from the time they were mated. When maintained on this diet and mated a second time, they conceived normally but most of the lambs were born dead or died within a day or two, and those ewes which reared a lamb had little milk. A subgroup of these ewes, which received large doses of vitamin A at intervals, gave birth to normal lambs which they nourished satisfactorily until weaning time. Blood-vitamin A levels in the ewes which received no supplement were extremely low and many of their lambs showed gross enlargement of the thyroid gland. Reference was made to this work in the Annual Report for 1950-51.

During the year, 250 weaners were used in drought-feeding experiments with different maintenance rations comprised of wheaten chaff and wheat, supplemented with ground limestone. One group received wheaten grain alone with no roughage. Half the weaners in each group received a single large dose of vitamin A (500,000 I.U.) soon after the trials commenced. The trials continued for seven months thereafter. During the first three months, the death rate was low throughout. Subsequently, it remained low among weaners which had received additional vitamin A but increased progressively among the others; 79 deaths occurred, seventeen among the treated weaners and 62 among the untreated. During the last three months of the trial the difference was particularly striking—only four died among the treated weaners, compared with 42 among the untreated.

This suggests that a single large dose of vitamin A, which can be given by the mouth, at an approximate cost of 1s. a head, would prevent many of the losses which occur, among young sheep especially, during droughts of several months' duration. Similarly, treatment of ewes well in advance of lambing, if this is to occur during drought conditions, should prevent many of the lamb losses which are so common under these circumstances. Such treatment is of no avail if the ewes are about to lamb. It must probably be applied not later than the fourth month of pregnancy, but further work is required on this point.

7. Toxicity of Large Rations of Wheat.

In the last Annual Report it was stated that it was not then known how far the lactacidaemia and acidosis which follow excessive consumption of wheat are consequences of the severe fall in blood volume and whether this is osmotic in origin or is due to bowel injury. Further work has shown that fall of blood volume can be produced osmotically in sheep by introducing appropriate amounts of glucose into the rumen or subcutaneously. In the first case, blood volume decreased 40 per cent., comparable to that occurring in an advanced case of wheat intoxication. There was a slight fall of blood pH and a slight rise of blood lactate, but blood bicarbonate increased considerably. In the second case, severe fall in blood volume also occurred (31.5 per cent.), but the blood lactate did not rise and the blood pH, far from falling, increased slightly. There was thus no evidence that in the sheep acidosis or lactacidaemia necessarily follow severe fall in blood volume. Further work on the effect of "Aureomycin" in preventing the toxicity of wheat has shown that the addition of the crude product "Aurofac", donated by Messrs. Lederle, United States of America, at the rate of 11.5 g./kg. completely prevented toxic effects from consumption of an otherwise certainly lethal amount of wheat. Although ruminal lactic acid increased to 1.2 per cent., and the ruminal pH fell to 4.6, yet blood lactate did not exceed 100 mg. per cent. and little change occurred in blood pH, bicarbonate, or volume and the sheep recovered within a few days after very slight effects. The implications of this experience are being studied.

A great amount of work has been devoted to a study of the buffering capacity of the rumen and the relationship of the partial pressure of carbon dioxide to this, to ruminal pH, and to ruminal bicarbonate. This has led to development of a technique for estimating the pH of the rumen of the intact sheep from aspirated samples taken by stomach tube. These studies have emphasized the cardinal importance of the carbonic acid buffer system in the rumen.

The toxicity of other cereal grains has also been studied. Ground oats, barley, or maize were administered to sheep in amounts calculated, on assumed average starch content, to be equivalent to the known lethal dose rate of wheat grain. All sheep developed low ruminal pH, high ruminal lactate, and high blood lactate, but variation was found in the degree of acidosis. Some sheep died, others gradually overcame the acidosis and recovered. The dose rate was apparently marginal, but, if it were exceeded a little, death would regularly follow. Those sheep which recovered were later shown to be susceptible to lethal amounts of wheat grain. Fluid from a fatal case of wheat intoxication has been tested on mice for the presence of bacterial toxins, without positive results.

8. VITAMIN A REQUIREMENT.

The experiment mentioned in the 1950-51 Annual Report has been completed by the Division of Biochemistry and General Nutrition. In 1951 ewes, which had been on a seriously restricted intake of carotene for more than three years, lambed satisfactorily—even the group which received each day during gestation only 25 μg. of carotene/kg. body wt. The effects of another lambing after further depletion were studied in 1952. One of the ewes on the basal ration died and none of the others produced lambs which survived more than a few hours. Only one ewe in the 25 μg. carotene group produced a lamb which survived. Lambing was successful in the group which received 50 μg. carotene. Thus it is apparent that a daily intake of 50 μg. carotene/kg. body wt. during gestation is sufficient to ensure that mature ewes reproduce satisfactorily even though their reserves of vitamin A have previously been depleted to a very low level. The results are being prepared for publication.

9. THE CAPACITY OF SHEEP TO DEAL WITH NITRATE.

Young, vigorously growing pasture plants may accumulate sufficient nitrate to be definitely harmful and at times fatal to grazing animals. In the Division of Biochemistry and General Nutrition a study is being made of the nature of this hazard and of the mechanism of the toxic effects of nitrates and nitrites. Single doses of 15 g. sodium nitrate administered to normal adult sheep on dry rations is well tolerated although considerable (up to 50 per cent.) conversion of the haemoglobin in the blood to methaemoglobin takes place after 3-5 hr. The methaemoglobin formed in this way reverts slowly to haemoglobin in the ensuing 24 hr. Sheep which received 30 g. sodium nitrate/day in two doses at intervals of 8 hr. survived for 4 weeks although the methaemoglobin did not fall below 10 per cent. and frequently exceeded 60 per cent. of the total haemoglobin during this period. Larger and more frequent doses killed the animals within a few hours. The hazard of nitrate poisoning, although real, is not likely to be a serious one. Experiments are proceeding and observations of the seasonal and diurnal changes in nitrate concentration in the tissues of certain plants grown on a number of areas are being observed.

10. CHRONIC FLUOROSIS.

One of the two experiments being conducted by the Division of Biochemistry and General Nutrition has been concluded. The liveweight and wool production of individuals in the groups of mature sheep that had access to drinking water containing fluorine, as fluoride, in the respective concentrations of 0.3, 10, and 20 p.p.m., were not significantly different. No signs of chronic fluorosis were observed during the periodic inspections of the incisor teeth during the two-year course of the experiment, and no evidence of selective abrasion of the molars was found at autopsy when the experiment was concluded. There was no evidence that the quantity of fluorine ingested from water at these concentrations had any adverse effect on the capacity of the ewes to conceive and deliver healthy lambs. These findings indicate clearly that the hazards of chronic fluorosis are by no means serious if the animals are mature (about three and a half years of age) before they have access to drinking water containing relatively high concentrations of fluorine. It is with younger sheep that trouble may be expected. In the corresponding experiment with lambs born of ewes which had access to water containing the above concentrations of fluorine, there is already ample evidence of lesions in the teeth which later may seriously impair the well-being of the animals. Mottling and differential wear in the incisors are very obvious in the individuals of the 20 μg. fluorine group and abnormalities are quite marked in the teeth of those whose drinking water contained half of this concentration of fluorine. Although there is as yet no significant effect on the general health and productivity of the animals it might be expected that these early changes in their dentition will later give rise to adverse changes which will limit the well-being of the animals and be reflected by impaired growth and wool production. Observations are being continued to assess the magnitude of these untoward effects.

11. MINOR ELEMENTS IN ANIMAL NUTRITION.

The work of the Division of Biochemistry and General Nutrition has been continued in the laboratory and at the field stations.

(*a*) *Cobalt Metabolism in Ruminants.*—The main findings from experiments are:

(i) *Prevalence of Cobalt Deficiency.*—The experimental observations which have proved the very widespread prevalence of nutritional disabilities imposed on grazing ruminants by the incapacity of the pastures to provide sufficient cobalt were outlined in the 1950-51 Annual Report. The publication of maps showing the widespread distribution of cobalt deficiency in southern Australia has led rapidly to the use of cobalt-containing licks, &c., as supplements for flocks in areas distinct from those where the deficiency is very acute, and with the improvement of the cobalt status that has followed, the general health and productivity of flocks grazing over extensive areas, where the limitations due to cobalt deficiency had previously not been suspected, have been dramatically improved.

(ii) *The Function of Cobalt in the Metabolism of Ruminants.*—A series of experiments conducted in the field at the Division's Field Station at Robe, South Australia, in pens, and in the laboratory, have provided complete evidence that the syndrome of cobalt deficiency in ruminants is the result of a profound deficiency of the cobalt-containing vitamin B_{12}. The experiments reported in 1943-44, which showed clearly that cobalt must be administered *per os* to be effective for the prevention or for the cure of the malady, focussed attention on the nutritional importance of cobalt for the development of some at least of the mixed population of micro-organisms which normally inhabit the rumen, and indicated that cobalt might primarily exert its activity by favouring the proliferation of those organisms which are responsible for the production of accessory food factors essential for the animal. This has now been proved unequivocally. The sheep obviously requires relatively large amounts of vitamin B_{12} and, when a limit to the proliferation of those organisms in the paunch which synthesize vitamin B_{12} is not imposed by a shortage of cobalt, the amount produced there is large and a great proportion of it is available to the animal.

The nutritional effect of cobalt is apparently wholly concerned with the production of vitamin B_{12}. Parenteral injection of the vitamin was proved without doubt to overcome the whole of the disabilities of cobalt deficiency; deficient animals were found to respond to this treatment at least as rapidly as to a supplement of cobalt administered *per os*. Critically conducted balance experiments have shown unequivocally that the overall digestibility of the rations is unaltered by a state of deficiency which, if uncorrected, will lead to the death of the animal. The failure of appetite, which is the most striking feature of the deficiency syndrome, is thus a reflection of a metabolic defect in the animal's tissues. The unique intermediary metabolism of the ruminants, and the fact that these animals require very much more vitamin B_{12} than non-ruminant animals, provide a hint of what this defect may be. Experiments have been started to investigate the link in the chain of metabolic events in which vitamin B_{12} plays a part.

There is no evidence that cobalt performs any physiological function in the tissues of animals other than as a constituent of vitamin B_{12}. This vitamin is unique; it originates in Nature only as a metabolic product of certain micro-organisms, and is absent from the higher plants upon which the animal ultimately depends for food. The observations outlined above complete an important chapter of nutritional physiology which began seventeen years ago in this Division with the discovery of the great importance of cobalt in the nutrition of sheep.

(iii) *The Quantity of Cobalt Necessary for Complete Nutrition of the Sheep.*—The experiments to determine the minimum amount of cobalt necessary to fulfil the nutritional requirements of sheep have now been completed with the findings that a total ingestion of between 0.07 and 0.08 mg. Co/day is the smallest quantity that will suffice. It follows that a fodder containing between 0.08 and 1.0 μg. Co/g. dry wt. is about the lowest limit in respect to cobalt.

(iv) *The Control of Cobalt Deficiency.*—Experiments with sheep, reported previously, indicated that to be most effective cobalt should be administered frequently. As an aid to the husbandry of flocks depastured on incipiently deficient terrain, a series of experiments has been carried out to determine the relative efficacy of widely spaced dosing with quantities of cobalt much greater than those that would be required if administered at frequent intervals. The findings leave little doubt that dosing once every four weeks with 140 mg. Co *per os* will maintain Merino ewes in normal health while grazing on acutely deficient pastures. The results of such treatment on the second crop of lambs will be observed. The procedure indicated should find widespread favour in practice, especially in the extensive areas where the appearance of cobalt-deficiency symptoms is not a constant event from season to season.

(*b*) *Copper Deficiency in the Sheep.*—The methods evolved by the Division of Biochemistry and General Nutrition for combating the maladies which ensue when sheep are depastured on copper-deficient areas are now universally employed in husbandry practice in the affected areas. However, virtual copper deficiency may occur in areas where the copper concentration in the fodder is apparently sufficient and the factors affecting copper metabolism are therefore being studied.

(i) *The Effect of Molybdenum on the Copper Metabolism of Sheep Depastured at Robe.*—It was indicated in the previous Annual Report that an excessive amount of molybdenum (50 mg. and 100 mg. Mo/day as molybdate) administered to sheep depastured on the copper-deficient pastures at the Division's Field Station at Robe, South Australia, tended to decrease the rate of depletion of copper from the liver, to maintain the concentration of copper in the blood, and, paradoxically, to accentuate the symptoms of copper deficiency. These findings were so surprisingly different from those of other experiments conducted by the Division elsewhere, that they invited confirmation. The experiments were repeated and the results led to identical conclusions. These findings have helped considerably to clarify the existing knowledge of induced copper deficiency and to explain many apparently anomalous phenomena. Experiments at Robe to examine especially the nervous sequalae of copper deficiency are being continued.

(ii) *The Effect of Molybdenum on the Copper Metabolism of Sheep Depastured at Glenthorne.*—Experiments similar to those reported above were conducted with experimental groups of sheep depastured at the Field Station at Glenthorne, South Australia. Here, molybdenum increased the rate of depletion of the copper reserves of the animals when the copper content of the pastures was insufficient to maintain the sheep in positive copper balance, and decreased the rate at which copper was laid down in their livers when the concentration of copper available from the pastures was in excess of the animals' requirements. Dosing sheep in this area with 50 mg. Mo/day over a period of three years had no significant effect on their well-being as measured by their body weights and their wool production. Nor was the nature of the wool fleece affected in any way. At no time during the term of the experiment was the concentration of copper in the liver of any individual reduced to a level at which copper-deficiency symptoms appear; nor was the concentration of copper in the blood of the molybdenum-treated animals at any time abnormally low or significantly different from that of the untreated controls. These experiments have been completed.

(iii) *The Effects of Molybdenum and Tungsten on the Copper Metabolism of Sheep Confined in Pens.*—To secure more easily controlled experimental conditions a series of studies was carried out to determine the response of sheep to molybdenum on constant rations of known composition when the animals were confined in pens. Sheep on rations comprised of chaffed cereal hay and crushed wheat from which the total intake of copper was 3.5 mg. Cu/day, lost copper steadily. The concentration of copper in their livers fell exponentially over the first year of observation from the original mean of 190 μg. Cu/gm. dry wt. to a mean of approximately 40 μg. Cu/gm. dry wt. at which level it stayed during the subsequent year. Molybdenum (50 mg. Mo/day as molybdate) increased the rate of depletion but the final level was not significantly different from that of the controls. Tungsten (50 mg. W/day as tungstate) had no effect on the rate of depletion. A supplement of copper (5 mg. Cu/day) was just sufficient to maintain the sheep's copper status at its original level when added to the ration. When the equivalent amount of copper was administered as a drench three times a week, the copper status increased steadily. In another experiment similar sheep on different rations, comprising chaffed cereal hay and lucerne, from which the total copper intake was only very slightly higher than that of the controls in the above experiment, tended to improve their copper status. The copper status was judged in all experiments from the concentration of copper in the livers as estimated in samples collected by aspiration biopsy. These experiments are being continued.

(iv) *The Effect of Molybdenum on the Copper Metabolism of the Rat.*—To illuminate further the effects of molybdenum on copper metabolism several series of experiments have been made with rats. The results confirm the findings from the experiments with sheep. Moderate amounts of molybdenum administered to the rats led to increased storage of copper in the liver, to increased levels of copper in the blood, and paradoxically, as with the sheep at Robe, it precipitated symptoms of copper deficiency in animals that were receiving only just sufficient copper to maintain normal physiological function in the absence of molybdenum.

(*c*) *Field Experiments, Robe.*—Several of the major experiments described above have been carried out at the Field Station at Robe. In addition the following experiments are being conducted there.

(i) *The Effect of Top-dressing Copper-deficient Pastures with Copper Sulphate.*—Analyses of liver samples taken from the experimental animals by aspiration biopsy have again shown that sheep, whose only source of copper is from the pasture which was treated by top-dressing with copper sulphate in 1939 and 1940, have maintained a relatively constant copper status which is barely adequate. The mean concentrations of copper in their livers and in those of a group depastured with them which received a supplement equivalent to 5 mg. Cu/day were 55 and 510 μg. Cu/g. dry wt. respectively.

(ii) *The Effect of Top-dressing Cobalt-deficient Pastures with Cobalt Sulphate.*—The effects of top-dressing the pastures of this area with cobalt sulphate in attempt to control cobalt deficiency were discussed in the previous Annual Report. Several years of careful observation of experimental groups grazed on pastures treated in this way showed clearly that the procedure is not a feasible means of control of cobalt deficiency in this area. These experiments have been terminated.

(iii) *Copper-deficient Lesion in the Wool of English Breeds of Sheep.*—After two years of observation there is unequivocal evidence that the Border Leicester, Romney Marsh, and Dorset Horn sheep all develop the copper-deficient lesions in their fleeces when grazed on copper-deficient pastures for a period sufficient to lead to depletion of the animal's copper reserves. The lesion is more striking in the closely crimped fleece of the Merino. In each breed appropriate supplementation with copper dramatically restored the normal fleece characteristics. The lesion in the broad-crimped Lincoln wool has not yet been identified with certainty.

(*d*) *Field Experiments, Keith.*—On this consistently copper-deficient terrain a single dressing of 7 lb. copper sulphate/acre has maintained for seven years a satisfactory copper status in grazing sheep. This experiment has been concluded.

(*e*) *Field Experiments, Borrika.*—The findings at this experimental site have been similar to those at Keith, although during the last two years the copper status of sheep grazing on the untreated pastures that were otherwise comparable with those treated with copper has not been particularly low (23 and 45μg. Cu/g. dry wt. of their livers respectively). This area is typical of incipiently copper-deficient terrain.

(*f*) *Field Experiments, Glenroy.*—Results have shown that top-dressing of 1 lb. cobalt sulphate/acre applied once only to these particular soils (Rendzina) is a simple, efficient, and economically feasible means of controlling cobalt deficiency for at least five years. This experiment has been concluded.

(*g*) *Field Experiments, Kybybolite.*—In this area no traces of copper deficiency have been observed in the experimental flocks during the past six years. Observations at this site have been concluded.

(*h*) *Field Experiments, "Brecon", Keith, South Australia.*—The reasons for setting down an experimental site at "Brecon", near Keith, South Australia, have been outlined in previous Annual Reports. Briefly, the site is typical of large tracts of very deficient virgin country in the Ninety-Mile Plain, on which, by applying the procedures indicated by the Division's researches, extensive areas of pastures are being developed. At the "Brecon" site a series of experiments with carefully matched flocks was begun in 1951 to assess the productivity of pastures sown in 1949 for this purpose, and to indicate nutritional factors which limit their usefulness as fodder for grazing sheep.

As this type of terrain was known to be incipiently cobalt deficient, the first series of experiments was designed to study the capacity of three kinds of pasture to provide sufficient cobalt to fulfil the requirements of breeding ewes and their lambs. During the first two years of observation of the experimental flocks there, no indication of cobalt deficiency has been observed. During the first year, however, there was a serious outbreak of a demyelinating malady, "Phalaris staggers", among the flock depastured on the area sown with *Phalaris tuberosa,* subterranean clover, and lucerne; it was absent from the flocks on the areas sown with lucerne and with subterranean clover.

Of the animals which had access to the young shoots of phalaris, none of those which received extra cobalt (7 mg. Co/week *per os*) developed the malady, whereas, of those which were depastured with them, but which received no supplement of cobalt, 70 per cent. developed the malady and 50 per cent. died of it. This protection afforded by cobalt was as unforeseen as it was convincing. Whether these striking effects were due to changes in the nature of the microflora of the rumen which led to destruction of the neurotoxic substances in the fodder or whether the increased supply of vitamin B_{12}, which additional cobalt would ensure, allowed the tissues to destroy the toxic substances before they could accumulate in sufficient concentration to lead to demyelination, is not yet clear. Experiments are being conducted to illuminate this point.

In 1952 there was another outbreak of the malady, not as severe as in 1951, and, so far, 7 mg. Co/week has again afforded complete protection, although several untreated animals, as well as some which have received less frequent doses of cobalt, have been affected.

The findings are of considerable importance as the high-yielding perennial grass *P. tuberosa* is admirably suited for pasture development in southern Australia and has been and is being extensively used for the establishment of permanent pastures. It seems likely that outbreaks of phalaris staggers, which occur at erratic intervals among flocks depastured in this grass, is in part due to the cobalt (vitamin B_{12}) status of the sheep; erratic seasonal outbreaks of cobalt deficiency in flocks on incipiently cobalt-deficient terrain have been stressed previously by the Division, and it is not improbable that relatively high concentrations of the toxic principle are always present in young *P. tuberosa* but only occasionally are animals unable to deal effectively with it. These experiments are being continued.

12. INFERTILITY AND PHYSIOLOGY OF REPRODUCTION.

(*a*) *The Influence of Nutrition on the Performance of Breeding Ewes.*—Groups of ewes, which were maintained on drought rations throughout pregnancy, received additional feed for different periods prior to lambing. The results were inconclusive, but the experiments are being repeated.

(*b*) *Infertility in Ewes on Clover-dominant Pastures.*—Work in this co-operative investigation was confined largely to laboratory work on chemical and biological assay of the pro-oestrogen in the clover, and further studies of the effects of oestrogens on small experimental animals and on sheep. The results seem to show that sheep differ from small experimental animals in that they develop a persistent infertility after a course of oestrogen administration whereas the small laboratory animal quickly recovers. Good progress was made in the development of a chemical method for the analysis of plant material for the pro-oestrogen, genistein. This was done by an officer of the Department of Agriculture of Western Australia working in the Animal Health and Nutrition Laboratory of the Department.

(*c*) *Seasonal Variation in the Level of Fertility in Merino Sheep.*—A systematic study of the seasonal variation in the level of fertility was started on a flock of 550 ewes. On a group of 40 ewes, periodical direct observations were made on the ovaries. On a group of 480 ewes, the results of mating 120 ewes for a period of two months at four periods of the year were studied. The first mating was in July-August, 1951, the second in September-November, 1951, the third in December, 1951-February, 1952, and the fourth in March-May, 1952. An X-ray examination of 40 ewes in each group was made at 12, 15, and 18 weeks after mating to determine foetal development. Another 40 ewes were slaughtered at from three to four weeks after mating for direct observation on the contents of the uterus. The remaining 40 ewes of each group of 120 were not subjected to special examination during pregnancy. From the first group, mated in July-August, 1951, 72 per cent. of lambs were available at marking time. Loss of fertility resulted from the failure of 10 per cent. of the ewes to mate. Early embryonic mortality occurred in from 5 to 10 per cent. of the animals mated. Failure to conceive or early death of the embryo occurred in 16 per cent. of the matings. The experiment is proceeding as results from the later matings become available.

(*d*) *Studies on Mechanism of Fertilization and on Gametogenesis.*—These studies in which the small laboratory animal is being used, have been continued.

(*i*) *Observations on Living Eggs.*—Examination of freshly recovered eggs at different intervals after ovulation has shown that the changes in formation and growth of pronuclei, previously observed *in vitro,* also occur *in vivo.* Measurements of nuclear and nucleolar diameters at different stages of fertilization have enabled more precise description of the process of pronuclear development. Pronuclear growth proceeds rapidly and appears to be essentially complete in the first half of the interval between penetration by the sperm and segmentation (period of fertilization). Thereafter no further increase occurs in volume but the form and distribution of nucleolar material continues to change. The pronuclei appear to be the sites of great activity throughout the period of fertilization but, whereas during the first half of this period the purpose of this activity seems to be primarily anabolic, in the second half the activity is of a different nature and may conceivably involve a synthesis of "templates" necessary for embryonic growth. The function of fertilization is, clearly, not restricted to a mingling of maternal and paternal chromosomes, but a fuller explanation cannot yet be given.

(ii) *Histochemical Investigations of Pronuclear Development.*—Histochemical methods are being applied to eggs in various stages of fertilization and early segmentation in an attempt to discover the composition of the nucleoli and the distribution of nucleic acids. Results, so far, indicate that the nucleoli of rat pronuclei are similar to those described in the literature as occurring in other kinds of cells. The desoxyribonucleic acid seems to be absent from the interior of the pronucleus but to be distributed around its periphery as well as through the nucleoplasm. The distribution of ribonucleic acid has yet to be determined.

(iii) *The Nature and Properties of the Mammalian Egg Membranes.*—By careful use of histochemical methods, it has been possible to study more closely the matrix of the cumulus, the zona pellucida, and the so-called "albumen layer" which occurs only in the rabbit egg. The albumen layer is comprised largely of mucopolysaccharide. Although these three membranes are similar, in that they are all mucoproteins, the sperm can penetrate the matrix of the cumulus readily and the zona under special circumstances, but cannot penetrate the albumen layer at all. In the course of the work, the specificity of methods commonly used to demonstrate mucopolysaccharides histochemically, such as the periodic-Schiff technique and the reaction involving metachromasia, has been examined and defined more exactly.

(iv) *The "Capacitation" of Sperm.*—By allowing rats to mate at intervals after the time of ovulation, evidence has been obtained that the sperm must undergo some form of capacitation before it can penetrate the zona and that the female genital tract somehow participates in thus preparing the sperm, but the nature of the process is still to be determined.

(v) *The Passage of Sperm through the Female Tract.*—Data are being obtained by counting the number of sperms present in different parts of the tract at intervals after mating. The work is incomplete but initial results indicate that the uterotubal junction greatly limits the number of sperms which reach the site of fertilization. In the rabbit, sperms reach the site of fertilization in small numbers after 3-4 hours; at ovulation, some 10 hours after mating, about 1,000 sperms are usually present. At this time the ratio of the number of sperms in the uterus to the number in the tubes is of the order of 500:1. Restriction of the number of sperms which reach the site of ovulation probably minimizes the risk of polyspermy.

13. Breeding and Genetical Studies.

(*a*) *Inbred Flocks of Australian Merinos.*—The mean Wright's coefficient of inbreeding of the flocks remains at approximately the same figure as for last year, namely, 23 per cent. This coefficient should rise next year when the sires now in use are mated back to the first of their female progeny. Two flocks are not holding their numerical strength owing to low levels of fertility in recent sires. In the top-crossing experiment, differences between progeny groups from the first mating of inbred rams with non-inbred and unrelated ewes have not been observed. Progeny from the second mating have been obtained and the third mating has since been completed.

(*b*) *Inheritance of Component Fleece Characters.*—Matings have been continued for the purpose of building up numbers in the F_1 and F_2 generations. Data from fleece measurements on the first series of samples from F_1 females have been obtained. So far, they show about the mean of parental values for staple length, number of crimps per inch, fibre diameter, and density of fibre population. Mean values for clean-scoured yield appear to approach those of the higher yielding parent. The number of samples examined so far is too small for statistical analysis.

(*c*) *Sheep-breeding Studies.*—The main study is being continued at "Gilruth Plains". It consists of two parts, the first being concerned with a comparison of methods of selecting sires for general performance and the second with the results of selecting for and against single characters. The Section of Mathematical Statistics has continued to work in close collaboration with the Division of Animal Health and Production in these studies.

In the first part concerned with breeding systems, three closed breeding groups have been under comparison: the S series, where sires are selected on their own performance plus that of their half-sibs, the MS (mass selection) series, where sires are selected on their own performance only, and the C (control) series, where sires are selected entirely at random. The S and MS series moved into their third phase in May, 1952, when grandsons of the original rams were mated. For the first time all ram progeny were left entire and were available for selection at sixteen months of age. Selected rams in the S series had a mean clean wool weight 17 per cent. above the mean of all ram progeny in their series; the difference was also 17 per cent. for the five new series in the MS series.

Ewes entering the S and MS series were culled on paper only and all surviving two-tooth ewes were mated. (In previous years they were subjected to 30-40 per cent. culling on general performance.) If this practice is followed for a few years, the results of different methods of ewe selection can be calculated on paper and compared. Ewe selection will not be practised in the control series; when numbers have to be cut, ewes will be taken out at random.

To study the assessment of " performance ", measurements are made not only of clean wool weight but also of its five components—mean cross-sectional area and mean length of individual fibres, mean number of fibres per unit area, smooth body surface area, and increase in skin area due to wrinkling—as well as of reproduction record. One important aspect of the studies is the estimation of (i) the heritability of the characters being measured, (ii) the genetic and phenotypic correlations between them, and (iii) their relative economic importance. Estimates of heritability so far available indicate values of over 30 per cent. for clean wool weight and its five components, and values between 15 and 30 per cent. for length of gestation, birth weight, and weaning weight. Any genetic correlations found so far have high errors, but an indication of sign might be given in some cases. A strong phenotypic correlation has been found between number of fibres per unit area and fibre diameter; this is consistently negative but is not linear, the decrease in fibre diameter with increasing fibre number becoming smaller as fibre number increases. The genetic association is also negative. Degree of wrinkling and staple length are negatively correlated, and the genetic association is also probably negative. Degree of wrinkling shows a slight positive correlation with fibre diameter, but the genetic association is so far indeterminate. Staple length and fibre diameter show on the average a slight positive correlation, but this is by no means consistent either phenotypically or genetically, and some sire groups are characterized by long, fine fibres. Staple length and body size have a slight positive phenotypic correlation, but again the genetic association is indeterminate.

Further information on the inheritance of the measured characters will eventually be gained from the second part known as FS (family series). There are six closed groups in this series, the selections being for and against body size, for and against number of fibres per unit area, for and against staple length. The separation between the paired groups of progeny for each character is very marked. The mean body weight of unselected two-tooth ewes in the large size group in 1952 was 69 lb. and in the small size group 50 lb. The mean fibre number for the high fibre number group was 5,660/cm.^{2} and for the low fibre number group 3,820/cm.^{2}. The mean staple length for the long staple group was 8.1 cm. and for the short staple group 6.4 cm. Differences for the ram progeny were of the same order. The response of correlated characters will also be studied in these groups. This analysis will of course suffer from the disadvantage that each group was founded on one ram only, but the possibility of interesting combinations is being demonstrated. Both high and low fibre number groups, for example, had a short mean staple length in the two-tooths in 1952, while both staple length groups had a high fibre number, with fine fibres.

Another line of investigation is a study of the influence on wool weight and its components of factors such as age, breeding history, type of birth, and age of dam. Ewes from eighteen months to ten years of age have been under observation. Staple length has shown a decrease after two-three years of age. In dry ewes this has sometimes been offset by an increase in fibre diameter, but in lactating ewes the effect of lactation on fibre diameter has increased with age, producing a sharp decline in cut per head in the older ewes. Twin lambs have cut about ½ lb. less clean wool per head than singles at sixteen months of age, even when almost the same size; the chief source of difference lies in number of fibres per unit area. Progeny of two-year-old ewes also cut about ½ lb. less per head at sixteen months than the progeny of adult ewes, the fibre number again being less. Figures from other flocks have confirmed the observation that maternal influence affects cut per head when the progeny are two-tooths, both in twin lambs and in the progeny of maiden ewes. Although fibre numbers are not available for these additional observations, all other components of wool weight have been measured, and in the absence of differences between the other components the inference is that lower fibre number is the source of the lower clean wool weight in what might be called two types of " handicapped " progeny. This observation adds weight to the earlier finding that 60-70 per cent. variation in clean wool weight from sheep to sheep arises from variation in percentage skin cover.

(*d*) *The Study of Strains of Merino Sheep in Several Environments*.—This project is proceeding satisfactorily. The work at Cunnamulla and Armidale has been extended to a third centre at Deniliquin. The third crop of lambs from the original ewes was produced during the year, as well as the first lambs from ewes bred in the experiment. Body measurements, scores, and wool measurements are being continued. Subjective gradings of fleece characters have again been made by a worker from the East Sydney Technical College. An apparently satisfactory method of sampling twice yearly has been evolved to overcome the confounding of age and location brought about by the fact that lambing times are the same but shearing times are different at the three centres. The accumulation of data on characters at early ages is being continued by the " Gilruth Plains " staff so that the possibilities of early selection may be examined. In the winter of 1951, one-third of the sheep of all ages from Cunnamulla and Armidale arrived at the new area adjoining the Falkiner Memorial Field Station, Deniliquin; the experimental plan is now being completely carried out. These sheep were given a preliminary shearing in September, 1951, to bring all their fleeces to the same stage of growth. Lambing at this centre was carried out in temporary yards with some daily grazing on irrigated pastures, and for the time being mating is being carried out in the yards forming part of the new shearing shed unit.

An effective card record system has been developed. A model has been worked out for the analysis of data to separate the additive effects of strains and locations from interactions among strains and locations. It is being applied to the data from the purchased ewes in the first two years at " Gilruth Plains " and Armidale in those traits which were recorded at both centres. This procedure should test the proposed method of analysis and bring to light any need of modification. The results of these analyses may indicate the trends to be expected when data from the true experimental animals, i.e., those born on the field stations, are available in sufficient quantity.

An examination was made of the frequency of body strike in relation to fleece rot and other faults. At " Gilruth Plains " in 1950, the only occasion when serious fly strike occurred, the fine non-Peppin strain had significantly the least body strike. This parallels the situation at Armidale in 1949 and 1950, where this strain had very significantly the smallest number of animals affected by fleece rot and weather stain respectively. No data were available in which appreciable amounts of fly strike occurred together with the above faults. Consequently, it was not possible to examine this relationship on an intra-strain basis.

(*e*) *Studies on Hornedness in Sheep.*—A project was started in 1951 which aims to study the development of hornedness with age, the inheritance of hornedness, and any possible associated character in the fleece. During the year the sheep in the existing breeding trials at "Gilruth Plains" were scored for degree of hornedness. Selection for a high degree of hornedness has been practised in two families, each of approximately 40 ewes, and for a low degree of hornedness in two additional families of similar size. Reproduction and wool production data were collected from these families in addition to the frequent determination of the score for degree of hornedness.

14. BIOLOGICAL STUDIES OF THE SKIN AND OF WOOL GROWTH.

(*a*) *Comparative Studies of Breeds of Sheep: An Experimental Study of Lincoln, Corriedale, Polwarth, and Fine-wool Merino Ewes.*—Both stages of this experiment, and also the final laboratory analyses of the material collected have been completed. The statistical analyses necessary for its final publication are in progress. The results will be published as a series of short papers dealing with the relative performance of the four breeds under (i) unrestricted individual pen-feeding conditions, (ii) progressively restricted individual pen-feeding conditions, and (iii) natural grazing conditions, with moderate to high rainfall. In the course of this work an extensive study was made of the magnitude and sources of errors of estimation in the routine chemical fractionation of the greasy fleece. In addition, the experiment has provided material for a general study of the relations between fibre thickness and straight fibre length within the four breeds and under several planes of nutrition.

(*b*) *Comparative Studies of Breeds of Sheep: Field Studies of the Skin and Fleece.*—Field and laboratory procedures for both skin and fleece sampling in comparative studies have been further developed. In particular, the skin biopsy sample may now be regarded as an established method for a variety of experimental and other purposes, namely, genetic and physiological experiment studies of fleece growth and development in skin grafting, and as a diagnostic aid in skin and fleece abnormalities. Compact field equipment has now been designed. Flock sample studies of significant skin and fleece characters are being continued to cover the main Australian breeds and strains over a range of environments and seasons. The procedure with the skin samples has been extended to include other breeds of special significance by suitable arrangements with overseas colleagues. From this work valuable reference data and specimens necessary to the design and planning of genetic and physiological experiments are being obtained. Concurrently, an analytical study is in progress on the ecology of the Australian sheep population as far as this can be done from available recorded sources, e.g. the agricultural and pastoral statistics, and the various official stud registers of the breeds. Apart from the general orientating value of such population analyses, the information is of particular importance in selecting stock for experimental studies either in the field or the laboratory and in planning biological investigations.

(*c*) *An analysis of Skin and Fleece Characters in the Ewe Progeny of Sires in an Australian Merino Stud.*—By the use of essentially the same field and laboratory methods as mentioned in the previous paragraph, this study has proceeded for several years on a simple analytical basis in which the characters of unselected groups of ewe progeny by individual sires have been compared. A high proportion of the ev so measured are now part of the breeding flock a constitute about 10 per cent. of it. These ewes m now be classified on the basis of the laboratory measu ments made at a uniform age. A separate, sma highly selected breeding flock from among the measu ewes is now being formed. On all the animals such a flock selection will be based on laborat measurements and a breeding plan devised wh exploits this opportunity.

(*d*) *Experimental Histology of Skin and Hair.* (i) *Growth of Sheep Skin and Wool in Tissue Cultu* —Methods used previously for the skin of embryo mice were applied to the skin of a 70-day sheep foet Skin explants grew and differentiated in a medium plasma and chicken embryo extract for 38 days a produced keratinized wool fibres. Only central prima fibres were formed and these developed sebaceous glar but not sudoriferous glands. Further tissue cultures sheep foetal skin will be used to analyse the proc whereby the follicles are arranged in groups.

(ii) *Nutritional Requirements for Hair Growth Tissue Culture.*—The effects of varying glucose c centration on the growth of skin and hair in tiss culture were studied in skin explants from thirte day and fourteen-day embryonic mice. Explants fowl plasma and chicken embryo extract with 0.5 0.80 g. per cent. of glucose showed greater fibrobl outgrowth but no difference in rate of epidermal follicle differentiation compared with the control gro (0.15–0.19 g. per cent. glucose). Normal epiderm differentiation took place in 1.00–1.47 g. per ce glucose, but follicle formation and fibroblast outgrow were reduced. In 2.00–2.40 g. per cent. glucose, fib blast outgrowth and epidermal and follicle differenti tion were suppressed. In the first experiment on t effects of vitamin A supplementation on skin expla 5,000 I.U. added per 100 ml. of the culture mediu delayed epidermal keratinization and also the rate follicle differentiation. The addition of 500 I.U. h little or no effect.

(iii) *Analysis of the Role of Dermis and Epiderm in Follicle and Hair Fibre Formation.*—Commerc trypsin contains an impurity, probably an elasta which separates dermis from epidermis. Attemps split dermis from epidermis in the embryonic skin mice have been partially successful. Explants of pu epidermis usually degenerated, and there was no folli initiation or development unless some dermal tiss was present. Explants of pure dermis grew but d not form follicle papillae. However, a few epiderm buds embedded in split epidermis differentiated to t papilla and hair-cone stages in the absence of a co nexion with surface epidermis. The skin-grafti techniques used by Medawar and Billingham for ro ents have been adapted for use on the sheep. O aim in this work is to study the behaviour of trypsi split epidermis from one body region grafted to t dermis of another. In the preliminary work t spread of melanin pigmentation from black graft skin to the surrounding recipient areas was observ in the sheep. This phenomenon has been observ also by Medawar, Billingham, and others in guin pigs and cattle.

(iv) *Analysis of the Population Dynamics of Ha Follicles in the Skin of Sheep.*—The dynamics of pop lation growth and change among hair follicles in t skin of sheep is being studied, as one approach to t problem of understanding the definite characters the fleece staple and its component fibres. The pos bility of intrinsic competition effects occurring with the hair-follicle population, especially during grow and development, is being studied. Differences in fib size and the spatial relations of individual follicl are being used as initial criteria in this work and skin biopsy specimens from other experiments provide the necessary material.

(*e*) *Experimental Physiology of Skin and Hair.*—(i) *Anterior Pituitary Hormones and Wool Growth*—Previous work by an officer of the Division of Animal Health and Production, at the University of Cambridge, had established a technique of hypophysectomy in the sheep, and early studies were made on the mechanisms of pituitary regulation of wool growth. This work is now being continued and developed with a view to fractionating anterior pituitary extract and isolating the hormones particularly affecting wool growth. Associated with this work is the development of assay techniques for anterior pituitary hormones by the use of the hypophysectomized rat. The fractions so identified will be tested on the hypophysectomized sheep.

(ii) *The Function of the Skin in Relation to the Water Balance of Sheep.*—Experimental studies have been commenced to elucidate the mechanisms of water transfer through the skin of sheep and to determine the importance of this channel of moisture loss in relation to the total water balance under various conditions. Attention is focused for the present on establishing the degree to which thermogenic sweating occurs in the sheep and on the physiological mechanisms controlling the activity of the apocrine skin glands. Intradermal injections of adrenalin have evoked a demonstrable response but the threshold dosage required is somewhat variable.

15. SHEEP DISEASES.

(*a*) *Caseous Lymphadenitis of Sheep.*—These experiments were designed to determine the value of two possible methods of control of the disease. One is an annual pre-shearing vaccination, and the other the placing of the sheep directly "off shears" in a clean rested paddock. The experiment was commenced in 1946 when two groups of young wethers were submitted to one or other of the methods which were repeated each year until the animals were sent to slaughter. Further groups of wether weaners were brought into the experiment in 1947, 1948, and 1949. Drought and floods reduced the number of sheep in the experiment and also caused delay in the slaughtering of the groups. The first group, which was brought into the experiment in 1946, was slaughtered in July, 1951, along with a control group not subjected to either method. A careful examination of the carcasses in the slaughter-house showed that lesions of caseous lymphadenitis were present in 20.0 per cent. of the vaccinated group, 34.5 per cent. of the "clean paddock" group, and 47.2 per cent. of the control group. Thus the vaccination seems to have reduced the incidence of the infection by about half. A similar reduction was found in a previous experiment. The method of placing the sheep in a clean paddock off-shears seems to have brought about a slight reduction. Not until the later groups have been slaughtered and examined will it be possible to determine the true values of the methods. However, as the results from the vaccination are similar to those obtained in earlier experiments it seems that this method may have a limited value.

(*b*) *"Toxaemic Jaundice" of Sheep.*—The research work on this problem has been continued by the Division of Animal Health and Production in co-operation with the Veterinary Research Station, Glenfield, New South Wales, in the field, and with the assistance of other Divisions of the Organization and State veterinarians. Two diseases are involved—chronic copper poisoning and heliotrope poisoning. These diseases although distinct in cause and effect have been found to form a complex under natural conditions in the field. Investigation has continued in the field, where natural outbreaks of the disease have been studied, in flocks under experiment station conditions, and in the laboratory.

(i) *Chronic Copper Poisoning.*—Studies were continued at the Field Station at Cobram, Victoria, where crossbred sheep have been grazed on subterranean clover pastures maintained under irrigation conditions. The experimental flock has consisted of three main groups. Group A has been grazed on an area whose soil was made more acid by the use of sulphur. Group B has been grazed on an area whose soil was made more alkaline by lime. Group C has been grazed on an area whose soil was unmodified by any treatment. The growth of clover on the more acid soil had been unsatisfactory in the two previous seasons, but good germination and growth was obtained in 1952 after the first autumn watering by irrigation in February. In December, 1951, one animal in Group B and one animal in Group C died from chronic copper poisoning after having been travelled to the dip. About this time biopsy liver samples were collected from the animals in each group and were analysed for copper content. As the haemolytic crisis of chronic copper poisoning rarely occurs in sheep until the copper concentration reaches 1,000 p.p.m. or more, the proportion of sheep within each group that have reached this degree of concentration gives a measure of the susceptibility reached in each group. It was found that the proportion was 4.2 per cent. in Group A, 8.6 per cent. in group B, and 7.5 per cent. in Group C. In a group on natural pasture the mean liver copper concentration was approximately half of that of the sheep grazing the clover pastures and no animal had reached a concentration of 1,000 p.p.m.

In the other field experiment at Tumbarumba, New South Wales, drought had prevented the plans from being carried out. However, in the autumn of 1952, the sheep were placed on the prepared pastures.

The study of factors influencing the storage of copper in the liver has been continued in laboratory experiments. It was found that the nature of the plant material consumed as food had a definite influence on the amount of copper stored. Lucerne hay and oaten hay were compared in this study. The uptake or storage of copper in the liver was favoured by the diet of oaten hay as against the diet of lucerne hay. In one experiment in which the mean total intake of copper of the sheep on the two diets was adjusted to 15 mg./day and the molybdenum to 10.7 mg./day, the group on lucerne hay had a liver copper concentration of 299 p.p.m., compared with 1,300 p.p.m. in the group on oaten hay after the feeding experiment had been conducted for six months. In another experiment, which was conducted for three months, the copper intake per day was adjusted to 10 mg. on each diet. The group which received lucerne hay increased their mean liver copper concentration from 373 to 540 p.p.m., whereas the group receiving the oaten hay increased theirs from 361 to 857 p.p.m. The oaten hay had a low copper content, but a group of sheep maintained on it without any mineral supplement and whose intake was 2.9 mg. copper/day increased their mean liver copper concentration from 370 to 417 p.p.m. This is not a big rise but is very distinct from the fall that can occur on some diets with the same level of copper intake. It was also shown in this experiment that the action of molybdenum is profoundly affected by diet. On the lucerne hay diet, with an intake of 10 mg. copper and 10 mg. molybdenum per day, the mean liver copper concentration fell from 374 to 260 p.p.m. in the period of three months. On the other hand the same daily intake of copper and molybdenum caused a rise of liver copper concentration from 358 to 769 p.p.m. in a group of sheep maintained on the oaten hay.

(ii) *Heliotrope Poisoning.*—Field studies were continued at the Barooga Field Station, New South Wales. In the absence of summer rains, *Heliotropium europaeum* did not appear in the pastures. The sheep, therefore, had no opportunity to consume the plant although they had done so in the preceding years. Thus the number of animals dying from heliotrope poisoning was small and the amount of material for study was also small. The experiment, which commenced in 1949, has nevertheless confirmed field observations that Merino sheep do not eat the plant if other pasture plants are available for consumption, but that the common breeds of British sheep and their crosses with the Merino consume the plant and develop the disease. If Merino sheep are forced to eat the plant they prove as susceptible to the disease as other breeds of sheep.

The alkaloids present in the plant have been studied by the Division of Industrial Chemistry and two of them have been isolated and purified in sufficient quantity for experiments to be carried out on rats at the Animal Health Research Laboratory, Parkville. Small repeated doses of heliotrine have been injected into rats and the pathology of the disease has been studied. This alkaloid with relatively low toxicity has set up a hepatitis in rats which resembles the disease in sheep very closely. There is a megalocytosis of the parenchyma cells and an atrophic hepatitis with little fibrosis. The rats usually develop a haemoglobinuria.

It has been found that an appreciable proportion of the alkaloids may be present as the *N*-oxide which is non-toxic to rats in single large doses. It is possible that its continued administration may lead to the development of a characteristic hepatitis. Experiments to determine this were started during the year.

(*c*) *Sheath Rot.*—Observations were continued throughout the year by the Division of Animal Health and Production on a flock of wethers in the Western District of Victoria, which has been under observation since July, 1948. The sheep have grazed pastures which contain a high proportion of subterranean clover with ryegrass. It has been found that the incidence of the disease is lowest in the summer months but steadily increases through the autumn and winter to reach a maximum in the spring. The incidence in the summer is about 20 per cent. and rises to about 80 or 90 per cent. in September. The disease first becomes manifest as a small ulceration above the orifice of the sheath which may extend; there is scab formation. Many lesions remain static for some time and heal spontaneously. In a small proportion of cases the interior of the sheath becomes involved. In an experiment, 100 wethers, in which the incidence of disease was 60 per cent., were given testosterone as an implant. The incidence fell sharply to 20 per cent. but in the control group it rose to 77 per cent. In another experiment, a group of 309 wethers, in which the incidence was 47 per cent., was changed from the subterranean clover-ryegrass pasture to a pasture in which capeweed was dominant. Six weeks later all the animals were free from lesions. Half of the animals of the group were returned to the clove-ryegrass pasture and after 3 weeks the incidence had risen to 9 per cent. The others remained entirely free. The observations have thus demonstrated the importance of dietary factors in the occurrence of the disease.

(*d*) *Treatment of Footrot in Sheep.*—Observations in the field and experiments in the laboratory showed that sheep received no benefit from treatment with soluble sodium sulphamezathine either alone or with procaine penicillin. "Cetavlon" (cetyl-trimethylammoniumbromide) was also found to be ineffective when used as a foot-bath in 1.0 per cent. solution.

16. Internal Parasites.

(*a*) *Studies on Anthelmintics.*—(i) *Phenothiazine.*—It was mentioned last year that very finely ground phenothiazine appeared to be more effective than commercial grades of the drug. Trials carried out during the year have shown clearly that large particle size greatly detracts from efficiency. A sample in which 98 per cent. of the particles ranged from 46 to 76 microns in diameter was of such low efficiency that a dose of 20 g. left large residual infections with *Haemonchus contortus,* whereas 10 g. is usually highly effective against this parasite; a finely ground sample, in which 99 per cent of the particles were 10 microns or less in diameter was highly efficient, not only against *H. contortus* but also against less susceptible worm parasites such as *Trichostrongylus* spp. (black-scour worms) and *Oesophagostomum columbianum* (nodule worms). It was also found that an unsatisfactory commercial preparation of phenothiazine contained nearly 40 per cent. of particles exceeding 40 microns and a further 30 per cent. which exceeded 20 microns in diameter.

A short oesophageal tube for the administration of phenothiazine drenches to sheep has been designed and is being produced commercially. It can be adapted readily to automatic drenching guns of the usual kinds and is extremely simple to use. There is no danger to the sheep provided reasonable care is taken; no speed is lost and the full dose is administered with the certainty that none will be lost or left about the lips or mouth to cause staining of the fleece.

(ii) *Carbon tetrachloride.*—Doses of 2-8ml. injected into the rumen were ineffective against *Trichostrongylus* spp.; similar doses injected into the abomasum caused only very slight reductions in egg count. A field trial of the treatment of acute fascioliasis with carbon tetrachloride indicated that immature liver flukes are destroyed by increased doses of the drug. Assuming that the average period required for the liver fluke to reach maturity is 77 days, the results of the trial indicated that a dose of 1 ml. carbon tetrachloride will kill all flukes over 52-62 days old; 3 ml. will kill those which are over 37-52 days old, and 5 ml. will kill those which are over 17-37 days old. Confirmation of these results is being sought in a further trial at the laboratory under conditions which preclude reinfection. The shortage of supply of carbon tetrachloride has been aggrevated by insistence that, for drenching, the product must contain no free sulphur or carbon disulphide. The origin of this stipulation is not clear but it is probably intended as a possible safeguard against carbon tetrachloride poisoning, which occurs sporadically for reasons which are not yet known. Samples of commercial carbon tetrachloride which contained up to 0.06 per cent. carbon disulphide or 0.5 per cent. free sulphur were therefore tested for possible toxicity to sheep in 5 ml. doses, i.e. five times the normal dose. In no case was there any decline in the level of serum calcium nor any other sign of distress or toxicity to the sheep. The tests were necessarily limited; some 30 sheep were used.

(iii) *Other investigations.*—Some 72 compounds have been tested against *H. contortus,* usually at several dose rates, by injection into the rumen. Groups of compounds tested included diphenylamines, quinones, diamines, ethers, carbamates, and some relatively insoluble arsenicals. A number of compounds, known to have pronounced biological activity in other respects, were also tested, e.g. maleic hydrazide, heptadecylglyoxalidine and 2,4-dichlorophenoxymalonic acid.

The following showed some anthelmintic activity: *N,N'*-dibenzolethylenediamine, *p*-chlorophenyl phenyl sulphone, magnesium arsenate, copper pentachlorophenate, diphenylethylenediamine, phenylthiourethane, maleic hydrazide, 2-mercapto-3-(nitrophenyl-4,6,6-rimethyl)pyrimidine, benzoyl peroxide, hexachlorophene, 4,4′-dimethyldiphenylamine, *n*-nitrosodiphenylmine, 4-aminodiphenylamine, hydroquinone. Further ests are being made.

(*b*) *Studies on Resistance to Nematode Parasites.*—Among young sheep, raised under worm-free conditions and infested with larvae of *Trichostrongylus* spp. for the first time, the level of nutrition did not appear to influence either the establishment or the duration of the infestation, but those on a low plane of nutrition developed somewhat heavier infestations. Subsequently, when the resistance of both groups was challenged by a massive dose of *Trichostrongylus* spp. larvae, no lamb in either the high plane or the low plane groups developed an infestation of any consequence. Similar results were obtained in another trial with young sheep from the field, which could be presumed to have been exposed to trichostrongylosis previously. Both trials indicated that resistance to infestation with *Trichostrongylus* spp. depends more upon previous experience of the infestation than upon the plane of nutrition. Further studies are in progress.

Serological studies on resistance and immunity of sheep to helminthiasis have continued to make good progress. It was reported last year that in sheep infested with *H. contortus,* and in which "self-cure" had been induced by a further dose of larvae, a distinct but very transient rise in blood histamine occurred. Further evidence has been obtained that if no rise in blood histamine follows the administration of an appropriately timed dose of larvae, "self-cure" is not manifested and *vice versa.* The phenomenon is not confined to haemochosis but occurred also in relation to "self-cure" of trichostrongylosis. Although administration of *H. contortus* larvae to sheep infested with *Trichostrongylus* spp. will induce "self-cure", the reverse does not hold, and there is no rise in blood histamine. Larvae of *Ostertagia* spp. which, like *H. contortus,* inhabit the abomasum, will induce "self-cure" of haemonchosis. Addition of *H. contortus* boiled antigen to the blood of sheep known to be capable of manifesting "self-cure" did not result in any increase in histamine content. Injection of histamine, or of heparin, or of related chemical substances known to cause liberation of histamine in dogs and cats, such as "Stilbamadine" and "Compound 48/80", did not affect the worm infestations in sheep. In sheep which are slaughtered on the day on which the rise in blood histamine occurs, an oedematous change is evident in the mucous membrane. This change is confined to the abomasum in cases of haemonchosis and to the small intestine in cases of trichostrongylosis. Further investigation is required to determine the duration of this pathological change and its significance to the sheep.

The possible use of haemagglutination techniques for the detection of antibodies to nematode infections is being investigated and shows some promise.

Intradermal skin tests with 1/10 dilution of *H. contortus* boiled antigen have been made on many sheep with interesting results. Worm-free lambs and sheep which are infested with *H. contortus,* but fail to manifest "self-cure", show no reaction but infested sheep which do manifest "self-cure" show a large oedematous reaction within an hour. The development by sheep of resistance to haemonchosis, as distinct from "self-cure", is very irregular and a sheep which manifests "self-cure" may, nevertheless, contract severe haemonchosis from the dose of larvae which induced the phenomenon. Some sheep, however, become strongly resistant to infestation with *H. contortus,* though the duration of their resistance is extremely variable. Evidence is accumulating that such sheep remain skin sensitive to *H. contortus* antigen while their resistance endures. This test may, therefore, be a valuable aid in selecting such sheep for further study.

At Armidale, field investigations on resistance to *H. contortus* and to *Trichostrongylus* spp. have been continued. Administration of 52,000 infective larvae of *H. contortus* to five apparently resistant sheep produced no significant increase in worm population.

(*c*) *Epidemiological Investigations.*—Studies on population dynamics at the McMaster Field Station were prevented by lack of rain. In Tasmania a second series of trials began early in 1952. The trials in 1951 revealed general increases in the worm burden of sheep in late summer, reaching peaks in autumn and early winter and tending to decline in the winter months. Observations during several yearly periods are necessary before the regularity of these changes can be assessed, but it is clear that lambs born in late winter and spring may suffer severely from helminthiasis before weaning, and that further increase in their worm burden occurs in late summer and autumn. In Western Australia trials began in July, 1951, in the regions of Williams, Cranbrook, Toodyay, Kojonup, Beverley, Walebing, and Kellerberrin. So far these trials have shown sharp rises in *H. contortus* in only three of the regions, namely, Beverley, Walebing, and Toodyay in July-August, with a decline in October-November, and a second rise in January-February. At these times, similar changes in populations of *Trichostrongylus* and *Ostertagia* species occurred at all centres. *Chabertia ovina* populations increased somewhat later in the winter and continued further into the summer; there were rapid increases in February-March and some very heavy infestations were recorded. These trials in Western Australia and Tasmania are being conducted in collaboration with the respective Departments of Agriculture. In New South Wales a second series of trials were conducted during the year on the Southern Tablelands (Yass) where winter rains predominate. Although the season was much drier and worm burdens were much lighter in consequence than during 1950-51, the results have shown a similar trend, namely, an increase in spring and early summer, a second peak in the autumn and a considerable decrease after autumn rains. Similar trends in worm populations, but at a lower level, were also observed in an adjacent area (Goulburn) where the rainfall is not seasonal. Some groups of weaners were drenched monthly with phenothiazine or copper sulphate-nicotine sulphate mixture. Worm burdens were thus reduced to very low levels, but the levels in untreated sheep were also comparatively low, so that differences in body weight between treated and untreated sheep were not great.

At Armidale, studies of sheep on native pastures have continued. One group of "Chiswick"-bred sheep has been under observation since birth in 1948 and provides a comprehensive picture of the parasitic life-history of a group of non-drenched sheep grazing native pastures in the New England region. Of the original group of twenty, five sheep have died from the effects of worm parasites. Surviving sheep are apparently strongly resistant to *H. contortus* which caused four of the five deaths. The fifth died from the effects of *Oesophagostomum* infestation. With increasing age, the level of *Trichostrongylus* infestation has tended to decline, but *Oesophagostomum* infestation becomes more important.

Oesophagostomum infestation has been notably lower in lambs grazing sown pastures. A group of sheep grazing sown pasture has maintained a low worm burden without anthelmintic treatment.

Additional observations, which have a bearing on epidemiology, have been made during the year. They are as follows:—

(i) *Oesophagostomiasis and Grazing Oats.*—The effect of grazing on green oats during the winter months in ridding sheep of *Oesophagostomum columbianum* has been mentioned in previous Annual Reports. In sheep grazing on oats at the McMaster Field Station there was usually no reduction in infestation during the first two-four weeks but a pronounced reduction occurred if grazing were continued for longer periods. Sheep not previously infested with *Oe. columbianum* were dosed with infective larvae from four-seven weeks before commencing oat-grazing; heavy infestations developed in nine out of twelve and light infestations in the remainder. However, when such sheep grazed on oats for three-six weeks before they were dosed with larvae the resulting infestations were usually light and in five of the twelve sheep no infestation developed.

At Armidale during 1951, sheep grazing oats threw off their adult nodule worm population without appreciable increase in body weight. Previous experience had associated loss of worms with a marked increase in weight. Elimination of worms proceeded rapidly after introduction to the crop. Grazing of the crop also produced a softening of the faeces and a lowering of their pH. Where infestation was heavy, elimination of adults was not complete. The evidence available suggests that female worms were more readily removed than males. Oat grazing did not prevent emergence of fourth stage larvae from the bowel wall but apparently many larvae were eliminated before maturity. No information was obtained on the effect of oat grazing on the establishment of third stage infective larvae.

(ii) *Haemonchosis and Anaemia in Sheep.*—Red cell counts fluctuate appreciably during the course of infestations with *H. contortus.* In sheep which repeatedly manifest " self-cure " when dosed periodically with infective larvae, red cell counts may remain low although there are few eggs in the faeces. It is thought that the presence of immature worms may be responsible and that they may remain immature for long periods in sheep which are resistant to haemonchosis. In several instances, increasing egg counts and decreasing red cell counts have been noted several months after the last exposure to infection. This could result from a greatly lengthened period of immaturity of the parasites, or to adult females having been present throughout, but being prevented by the resistance of the host or some other mechanism from producing eggs in the usual large numbers. Increased egg production could be expected to require a higher food intake by the parasites and this, in turn, could further reduce the red cell count. The implications of these observations in the field and particularly in the interpretation of epidemiological observations, are being investigated.

(*d*) *Studies on* Ostertagia *spp.*—Infestation of the abomasum of sheep with *Ostertagia* spp. is very widespread in the southern parts of the Commonwealth. Heavy and damaging infections are often encountered and the position is complicated by the fact that the larvae of these species spend some days in a histotrophic phase, embedded in the abomasal mucosa, where they are inaccessible to anthelmintic drenches. The duration of this histotrophic phase is of obvious importance, therefore, and it is being closely studied. Worm-free lambs are being artificially infested for this work. The necessary infective larvae of *Ostertagia* spp. can be produced readily by incubating the eggs at somewhat lower temperatures than are usually required. The larvae enter the abomasal mucous membrane near the pylorus on the third and fourth days after infestation and are said to remain there for two days, but current observations indicate that they may remain there for considerably longer periods. The work is still in its early stages.

(*e*) *New Species of Nematodes in Sheep.*—*Nematodirus abnormalis* (May 1920) has been recovered from the small intestine of a number of sheep, some of which come from the Southern Tablelands of New South Wales. Previously only *N. filicollis, N. furcatus,* and *N. spathiger* had been reported in Australia. A previously undescribed nematode, which shows affinities both with *Trichostrongylus* and with *Asymmetrichostrongylus* (parasites of the wallaby, *Macropus* spp.) has been recovered from the small intestine of a sheep. The true host is not yet known; it is considered unlikely to be the sheep.

Minor morphological variations in certain species of *Trichostrongylus* and *Cooperia* have been noted, which may be of importance in taxonomic studies.

An index has been completed of all known species of *Trichostrongylus.*

(*f*) *Distribution of Nematodes in the Small Intestine of the Sheep.*—One of the objectives of this work was to determine whether parasites which are normally found in the duodenum might be dislodged by an anthelmintic but re-establish themselves successfully at a lower level in the gut. Apparently this does not occur as there is no difference between the shapes of the frequency distributions of *Trichostrongylus* species or of *Strongyloides papillosus* in drenched and undrenched sheep. No difference has been detected in the form of the distributions between heavy and light infestation. The constant positional relationships between the peaks of the distributions of genera which inhabit the small intestine of the sheep, as found by others, has been confirmed; it has also been found that the peak of the distribution curve of *T. rugatus,* and possibly of *T. probolurus,* coincides with the peaks of the curves of *T. vitrinus* and *T. colubriformis,* implying that these species all respond similarly to the stimuli which cause them to parasitize the duodenum. *Trichostrongylus* species occur principally in the first nine feet of the duodenum, the peak usually occurring between the third and sixth foot.

Erratic distribution has been said to indicate that the parasite is present in an abnormal host. Observations on the distribution in rabbits of *T. colubriformis* of the sheep have shown a somewhat erratic distribution and the distributions in sheep of the rabbit parasite *T. retortaeformis* and of the cattle parasites of the genus *Cooperia* in cattle and sheep respectively, are now being examined. It is hoped that the work will assist in elucidating problems of host specificity.

(*g*) *Studies on the Bionomics of Free-living Stages of Nematodes of Sheep.*—Only preparatory work has been done as yet. The literature has been completely indexed and is being reviewed; sampling techniques have been studied with a view to modification and improvement in recovery rate and repeatability.

(*h*) *The Pathology of Helminthiasis in the Sheep.*—This investigation commenced during the year. The histology of the alimentary tract of a normal worm-free sheep is being studied and a previously worm-free weaner has been infested with *Trichostrongylus* spp. larvae to provide material for histopathological study.

Plasma volumes of worm-free sheep and sheep with *Trichostrongylus* infestations are being measured at weekly intervals by Evans blue-dye technique and total blood volumes by haematocrit readings. Although clinical signs of trichostrongylosis are not yet apparent in the infested sheep, and infested and uninfested sheep have shown little difference, so far, in plasma volume relative to body weight, the total blood volumes of the infested sheep have declined, due to a fall in packed-cell volume, to a mean of 24.8 per cent., compared with 30.3 per cent. in the controls; the red cell count has fallen to about 6 million/cu-mm. in infested sheep compared with 11 million/cu.mm. in the controls. Haemoglobin estimations on two infested sheep and two controls gave average values of 6.1 and 9.1 g./100 ml. respectively.

(*i*) *Parasite Physiology and Toxicology.*—The year's work has dealt with certain aspects of parasite physiology which might assist in the development of chemotherapeutic agents, and with studies on the mode of action of phenothiazine.

(i) *Phenothiazine in the Tissues of Treated nimals.*—This work has been completed. It was esigned to determine whether appreciable amounts f phenothiazine derivatives are formed in the gut ontents of host animals, or in their parasites, and hether the nature of the derivatives formed differed n different animals. Only phenothiazine itself could e detected in the intestinal fluids of the rat and the hicken, but it appeared to be attached to a fatty substance from which it could not be separated by acid or lkaline hydrolysis. From these experiments, and rom others conducted *in vitro*, it is considered that henothiazine itself, and not its oxidation derivatives, s the anthelmintic agent.

(ii) *Studies on the Chemical Properties of Certain Anthelmintic Compounds.*—This work has dealt specially with phenothiazine and compounds likely to act similarly. The compounds are synthesized at the Chemistry Department of the University of Sydney and are screened for anthelmintic activity, against *Syphacia* spp. in mice, at the McMaster Laboratory. Excellent progress has been made. Various substituted phenothiazines and diphenylamines have been synhesized and their oxidation potentials have been measured in 90 per cent. acetic acid, with standard bromine solution in the same solvent. Results have shown a definite relationship between these potentials and the anthelmintic activity of the compounds. Both above and below a definite, and narrow, range of potential, activity vanishes completely; within this range of potential, anthelmintic values lie on a steeply peaked curve. Phenothiazine, phenoxazine and *p*-ditolylamine lie near the peak of the curve and it appears that no other compound can have greater anthelmintic value than the two latter. As yet, no anomalies have been encountered and no indication has been found that the anthelmintic activity of such compounds is related to any physical property other than oxidation potential. Further work is continuing and a report is in preparation.

(iii) *Physiology of* Ascaridia galli.—No lactic acid was produced by *A. galli* under aerobic or anaerobic conditions *in vitro*. This parasite, therefore, appears to have some special system for obtaining energy under anaerobic conditions and the energy from aerobic sources probably follows the normal route from glucose, via pyruvate, through the tricarboxylic acid cycle, as in *Nematodirus* spp.

(iv) *Studies on the Nucleic Acid Metabolism of the Malaria Parasite,* Plasmodium berghei.—Examination of blood from mice infected with *P. berghi* has shown a relationship between the ribo- and desoxyribonucleic acid content of the blood and the number of parasitized red cells. When 25 per cent. of red cells are infected, the ribonucleic acid (RNA) content is 25 times, and the desoxyribonucleic acid (DNA) twelve times the value for normal blood. Values for RNA and DNA content of the parasites have been calculated as: $RNA = 1.10 \times 10^{-7}$ and $DNA = 0.54 \times 10^{-7}$ μg./parasite. These figures, however, were obtained from blood which contained parasites at different stages of the asexual cycle and hence do not represent absolute values for any particular stage of the parasite. The purine and pyrimidine composition of RNA and DNA from *P. berghei* has been studied by means of paper chromatography. The purine: pyrimidine ratio for the parasite RNA was 1.40, compared with 1.35 for yeast RNA. The corresponding ratios for parasite DNA and thymus DNA were 1.04 and 1.12, and the value for DNA from mouse leucocytes was 1.17. Nucleic acids have also been demonstrated in *P. berghei* by cytological methods. The results of this work have been prepared for publication. The rate of turnover of various phosphorus fractions in *P. berghei* has been studied with the aid of P^{32} during 48 hour periods. Incorporation of P^{32} was greatest in the lipid fraction early in the period of observation and in the DNA later; the acid soluble phosphorus and RNA phosphorus fractions incorporated it much more slowly and the activity of the phospho-protein fraction was insignificant throughout.

(v) *Studies on the Biological Activity of Complex Ions.*—The complex ions which are being examined have been prepared in the Chemistry Department, University of Sydney. They have optically active *d*- and *l*-forms and an overall positive charge due to their metallic atom; the metal is so placed that it can play no part in biological activity; they have no "biologically active groups" and are not likely to undergo changes in the organism, nor under the conditions in which the *in vitro* experiments have been conducted. The compounds which are being examined have either asymmetric charged molecules, symmetric charged molecules, or neutral molecules. Toxicity studies on mice showed that the *d*-form was much more toxic than the *l*-form of the same phenanthrolene complex. The signs in affected mice resembled those induced by cholinesterase inhibitors. Atropine appeared to enhance the toxicity of the *d*-form and to render the *l*-form toxic in doses which otherwise caused no toxic symptoms. This effect of atropine is still unexplained. There is some experimental evidence that it affects the permeability of cell membranes but further proof is required. The *d*- and *l*-forms of the dipyridyl complexes were of approximately equal toxicity. From these experiments it appeared that the biological activity of these complex ions resulted from the poisoning of certain enzymes and *in vitro* experiments on isolated enzyme systems were commenced. The early results show that some of the complex ions affect certain enzyme systems profoundly, but they suggest that, in the living organism, other factors must modify the effects in various ways. Other findings from *in vitro* experiments on isolated enzyme systems may be summarized as follows:—to specific cholinesterase, certain asymmetric complexes were highly inhibitory, symmetric complexes much less so and uncharged molecules not at all; to purified histaminase, dipyridyl complexes gave stronger inhibition than phenanthrolines, the *d*- and *l*-forms having about equal activity, but symmetric and uncharged molecules showed no activity; the complex ions had no inhibitory action on the cleavage of purified yeast RNA by ribonuclease (nucleodepolymerase) nor upon the splitting of 1–6 fructose by aldolase (desmolase). Compounds which can be chosen for their specific action on selected enzyme systems are clearly of great potential value in a wide range of biological work.

(*j*) *Parasite Survey.*—In a survey in the New England Region of New South Wales, identification of parasites of sheep has been carried out. Several interesting records were made. The tapeworm, *Helictometra giardi,* was found to be more common than suspected and occurred in 8 per cent. of the sheep examined. It could be confused with *Moniezia expansa,* on superficial examination, which occurred in 20 per cent. of the sheep in the same series. *Oesophagostomum venulosum* was found in 39 per cent. of the sheep examined. This parasite is not usually associated with summer rainfall regions but the wet seasonal conditions prevailing during the past few years may have played a part in favouring these infestations which ranged in size up to 343 adult worms.

17. EXTERNAL PARASITES.

(*a*) *Studies on the Itch Mite of Sheep* (Psorergates ovis).—A systematic investigation of this parasite has been commenced. Its morphology has been examined in detail, with particular reference to its mouth parts, feeding mechanism, and motility. These mites appear to feed on the cellular fluids of the epidermal cells.

Observations on the living mites and examination of their mouth parts suggest that the palps, each armed with three minute bifid claws, are used to scrape the epidermal surface until the outer layer of living cells is reached. The chelicerae are then thrust out and either rupture the cell membrane, or tense it so that the stylets may be thrust through and the pharyngeal pump sucks up the cellular fluid. This procedure would explain the slight clinical manifestations and excessive scurf formation shown by affected sheep. The larvae and nymphs appear capable only of sufficient movement to permit feeding, but the adults move freely and can cover considerable distances. It is probably the adults which are transmitted from sheep to sheep. Itch mites may be recovered from any part of the wool-bearing skin surfaces of affected sheep, but have not been found on hair-bearing surfaces. They occur on the skin ridges between groups of wool follicles and about the follicular orifices. Larvae and nymphs have invariably been found in small depressions under the superficial layer of scurf, where they may be protected from insecticidal applications. Eggs have also been found under fragments of scurf. Eggs, larvae, two nymphal instars, and adults (the only stages observed to date) are commonly found together in skin scrapings. The life cycle probably occupies from one to two months; present indications are that all stages to maturity are passed through, with little movement, near the outermost living layer of epidermal cells, and that the adults wander freely and thus spread the infestation on the host and to other animals.

Much time has been spent in devising a special cell in which ectoparasites can be confined on the skin surface of the host. Good progress has been made and, if successful, the method will be of great assistance in studies on the life cycles of such parasites.

(*b*) *Systematics.*—A slide collection and taxonomic descriptions' list of ectoparasites of domestic animals in Australia has been commenced. It will be used for purposes of reference and identification.

(*c*) *Observations on the Deposition of Benzene Hexachloride on Sheep by Dipping and by "Fogging".*—This work is in abeyance owing to the absence overseas of the officer concerned. However, results of experiments conducted earlier in the year may be summarized as follows: From 4.26 to 17.8 mg. γ–BHC was deposited per 10 g. in the wool when newly shorn sheep were dipped in an emulsion-type sheep dip which contained 0.004 per cent. γ–BHC. Under similar conditions, the deposit left in the fleece of sheep which carried wool 1.0-1.5 in. long was of the same order of magnitude (range 2.5-20.2 mg./10 g.). The insecticide was found to be fairly evenly distributed through the fleece over the whole body surface and no significant difference in this respect was detected in samples from the back and sides. When fogs, generated in the "T.I.F.A." from 3.0 per cent. γ–BHC in oil, were blown into a 20-ft. by 30-ft. tent, particle sizes ranging from 90 to 200μ made little difference to the quantity of insecticide deposited; distribution within the tent was somewhat irregular, the area nearest to the inlet, but not in the direct flow of fog, received least insecticide; horizontal surfaces received up to ten times as much insecticide as vertical surfaces and up to twenty times as much as inverted surfaces; fleece samples from the backs of sheep in short wool, which were fogged with 3.0 per cent. γ–BHC in oil, gave a range of 10.0-105.0 mg./10 g. (mean 45 mg.), whereas samples from the sides of the same sheep gave a range of 1.0-50.0 mg./10 g. (mean 16.0 mg.); most of the insecticide is deposited in the tip of the fleece when sheep are fogged. Thus, although the deposit of γ–BHC on the fleece by fog was, in general, considerably greater than from dipping at the concentration recommended by the manufacturer, it was erratic in its distribution over the body surface and from sheep to sheep. Two further observations were made which have considerable practical significance, namely, the deposit from the fog was almost entirely confined to the tip of the fleece so that when sheep shorn to a 2-in. length of staple were fogged, no BHC could be detected in the lower half of the staple in most samples and only traces in others. Secondly, 50-76 per cent. of the BHC deposited on the fleece from fog disappeared within about ten days, much of it within the first 24 hours.

18. Sheep Blowfly.

(*a*) *Protection against Body Strike.*—Investigation of methods for the protection of sheep against body strike has been undertaken by the Veterinary Parasitology Laboratory, Yeerongpilly, Queensland. Owing to the severe drought which prevailed throughout Queensland during the late winter, spring, and summer of 1951-52, outbreaks of body strike did not occur. Arrangements were completed to carry out studies on body strike and its control under semi-field conditions at the Laboratory. Mass breeding of flies was successfully established and trials showed that the local population of *Lucilia cuprina* may be considerably increased in this way. A shower dip was installed. This will be used to induce fleece rot and to increase the susceptibility of experimental animals to body strike. The studies are being continued.

(*b*) *Ecological Studies.*—Previous work on blowfly ecology has given us a broad understanding of the factors which influence blowfly numbers; it has given information of the natural population density of *L. cuprina*; and it has shown that intensive trapping significantly reduced the incidence of strike. Further information is needed, however, before it can be decided whether or not blowfly control can be approached through direct attack on the flies.

The marking of flies is an important aspect of the ecological work, and a valuable method has been developed during the year whereby they are marked with dusts which fluoresce under ultraviolet light. The puparia are covered with a layer of sawdust impregnated with the dust so that in emerging they acquire a coating on part of the head. This marking persists throughout the life of the fly.

An experiment was conducted which involved the liberation of marked, newly-emerged and unfed *L. cuprina* near Canberra at a place surrounded by 40 liver-baited traps, situated at half-mile intervals along a radiating road system in an eight-mile diameter circle. These traps were cleared daily for six days with the object of obtaining data on the longevity and rate of maturation of the flies in the field.

An analysis of the trap catches indicated that the flies spread much more in some directions than in others; that the females lived longer than the males; and that the females had been able to secure a meal of protein, as shown in a study of the development of the ovaries. Contrary to expectations, because the weather was hot and dry throughout the tests, it was also evident that energy-producing food had been located.

It is expected that further information on habitat preference for this and other species will emerge when the data have been more fully analysed.

(*c*) *Biological Studies of Blowflies.*—The accumulation of knowledge about the other members of this important family has proceeded steadily. Life-history studies of *Calliphora* species show that three well-known species are specific predators on earthworms in the larval stage, and it seems probable that many other Australian species have this habit. There is little possibility therefore of these species ever becoming sheep blowflies.

The status of the two sheep blowflies *C. augur* and *C. nociva* is under investigation. Experiments suggest that most hybrid offspring are sterile. It seems likely, therefore, that these two species are genetically distinct in spite of the trifling anatomical differences.

Following English work, diapause (resting stage) was investigated in *L. sericata.* It was found that eggs laid by females captured in Canberra in late autumn produced larvae which entered a diapause, after feeding, even though hatched and reared at temperatures normally permitting development to proceed uninterrupted.

19. Other Investigations.

(*a*) *Neo-natal Mortality in Lambs.*—These studies have shown that, at "Chiswick" Field Station, Armidale, the majority of deaths between birth and marking occur within the first three days after birth. Among the factors that are of importance in such losses are (i) mothering ability of the ewe, i.e., its maternal instinct and milk supply, and (ii) lamb vigour. In some observations on mothering ability a small flock of Merino ewes was lambed under relatively close supervision. The ewes were six years old and had been mated for the fourth time. They comprised twenty ewes with a good lambing record, i.e., had reared a lamb in each of the three previous matings, and nineteen ewes with a poor lambing record, i.e. had lambed three times but at the most, had reared one lamb to marking. The lambing record of the two groups showed that the former reared nineteen out of twenty lambs and the latter group thirteen out of nineteen lambs. Although ewes with a good lambing record have a slightly better performance in respect to maternal instinct, birth weight of lambs, and lamb vigour than ewes with a poor lambing record, the chief difference between groups was in udder function. Ewes with a poor lambing record had a higher incidence of impaired milk secretion and this was associated with an increase in the number of lamb deaths. However, where one teat was blind but the remaining half of the udder functioned normally lamb losses were not affected.

Experiments have been carried out to investigate the effect of prolactin on the mothering ability of ewes. The hormone was used after lambing on ewes showing reduced or abnormal udder secretions, with or without poor maternal instinct. A total of eight Merino ewes (aged two to six years) and two Romney Marsh ewes (aged three years) was treated, while four Merino ewes were left untreated as controls. Dose rates were 500, 200, and 20 I.U. of prolactin per day, and the duration of the treatments varied from one to six days. In no case was there any marked improvement in maternal instinct attributable to prolactin. In cases with a thick udder secretion at parturition, it changed to normal colostrum in from 24 to 48 hours irrespective of whether prolactin was administered or not. In a further study in which three groups of Merino ewes were given 500, 200, and 20 I.U. prolactin per day for periods varying from two to nineteen days prelambing and three days post-partum, there was no improvement in maternal instinct or milk supply as measured by the growth of lambs during the first week, when compared with controls.

Observations were continued in 1951 on the effect of long wool and sweat dags about the flanks and udder on survival of lambs from ewes "lambed in the wool". Three groups were treated at crutching, six weeks before lambing, as follows: (i) normal crutch, i.e. removal of wool from posterior part of the udder and crutch area, (ii) normal crutch, plus the removal of the wool on the lower edge of the flanks and 3-4 inches anterior to the udder, and (iii) normal crutch plus removal of all the belly wool. In three years of observations the percentage of lambs reared has been slightly higher in the two groups in which more wool than normal was removed, but the differences have not been significant.

Records of lambing data, extending over four years, for a group of ewes originally mated as maidens in 1948, show that ewes which reared a lamb until marking in the first year had a better record of lambs reared in the three subsequent years, than ewes which either lost their lambs or failed to lamb as maidens. The differences are highly significant statistically.

(*b*) *The Effect of Grazing Management on Pasture and Animal Production.*—This is a co-operative investigation between the Division of Plant Industry and the Division of Animal Health and Production. The effect of different rates of stocking, rotational grazing, and grazing with different sizes of flock on the health and production of Merino sheep grazing native pasture, and the production of the pasture, have been studied. The trials comparing different rates of stocking (one sheep to three-quarters, one, and one and a quarter acres) and continuous and rotational grazing, are now in the fourth year. The hoggets grazing during 1950-51 have been retained during 1951-52. The trend in body weight, established during the first three years, in favour of the lighter rate of stocking has been maintained, and continuous grazing was again slightly superior to rotational grazing in this regard. Only slight treatment differences in wool production have been recorded. The heavier rate of stocking produces slightly less wool per sheep, but slightly more wool per acre. Parasite infestations have declined owing to seasonal and nutritional factors and to the increasing age of the sheep under trial. Sheep within each treatment group receiving phenothiazine each month maintain a significantly greater body weight than sheep not receiving anthelmintic treatment.

The size of flock trial which compares sheep in flocks of 2, 4, 8, 16, and 30 is in its third year. Treatment differences in body weight, wool production, and worm burden are not great. The mean body weight of sheep in the two-sheep flock, has continued at a lower level than in the other flock sizes.

(*c*) *Survey of Fine-wool Production.*—The field survey was completed in the early part of the year, after which whole time was devoted to the collection and examination of the data and the preparation of a report.

(*d*) *Subnormal Growth and Development of Young Sheep.*—The investigation in co-operation with officers of the Department of Agriculture in Tasmania was continued. The season proved to be a poor one and defects in the fleece of weaners became more apparent. Although these defects were indistinguishable from the straight steely wool of copper deficiency, examination of blood and liver samples failed to reveal a low copper status in the animals of the flock. Some deficiency signs were observed in the pasture and the investigation of these was started.

VIII. CATTLE.

1. General.

The Organization's work on dairy and beef cattle problems is being carried out within the Division of Animal Health and Production mainly at the Animal Health Laboratory, Melbourne, at the Vetinary Parasitology Laboratory, Brisbane, and at the McMaster Field Station, Sydney. The work is described in Sections 2, 3, 5, and 6 of this Chapter.

During the year arrangements were completed between the Australian Meat Board, the Queensland Department of Agriculture and Stock, and the Organization, for the purchase of two properties in Queensland for the investigation respectively of beef cattle breeding and of beef cattle pastures in northern Australia. Technical committees met to consider plans for the development of the properties and of the research programme. Steps were taken by the Organization to acquire tropical breeds of cattle from overseas countries for the work on the cattle-breeding station. Plans and arrangements were sufficiently advanced so that the co-operative investigations should begin during the next year.

Work on cattle tick by the Division of Entomology is reported in Section 4. The work of the Division of Plant Industry on pastures (*see* Chapter III., Sections 15-22 and 23(*e*)) is also of importance to the cattle industry.

2. CATTLE DISEASES.

(*a*) Pleuropneumonia of Cattle.—Attempts are being made to increase the keeping qualities of vaccine by dessication. So-called lyophilized vaccine has been under test for 2 years. The number of living organisms fell from about 10^9 ml. before drying to about 6×10^6 ml. (when reconstituted) after 2 years' storage at room temperatures. To determine whether this will satisfactorily immunize cattle, a trial with 30 head was put under way. All but four gave some serological evidence of "taking", although there was an unusual delay of about 35 days in reaching the peak of reaction. Tail reactions were mainly negligible or very mild, although five reacted more definitely. The immunity of the animals will be challenged in due course.

Because of reports that a certain pastoral property has had unsatisfactory results with standard vaccine, autogenous vaccine was used to vaccinate a group of 30 cattle, and they also will be challenged in due course. As was to be expected, with vaccine prepared from a freshly-isolated field strain, the tail reactions in some animals were severe, and two animals died. Unexpectedly, tail reactions in seventeen were hardly perceptible. In order to obtain information on the reaction of calves to vaccination and on their capacity to develop immunity, calves of various age-groups are being examined. To date 30 calves between five and seven months old have been vaccinated. None gave a tail reaction and none developed arthritic lesions. The serological responses were absent or poor in most cases. The effect of dipping in arsenical dips almost immediately after vaccination was investigated. It was found that the organism in vaccine is very sensitive to dip or to arsenite, so that very slight entry of dipping fluid into the tissues after vaccination would be expected to kill or retard the organisms. However, a trial on cattle vaccinated by the seton method in order to increase the opportunity for arsenite penetration showed that in practice the setons are quickly soaked in blood or lymph which clots and prevents significant penetration of arsenite.

A blood test has been developed that can be applied to animals in the field, which yields results in a few minutes and which requires only a drop of blood from the ear. Work is proceeding to define its sensitivity and accuracy, but experience to date suggests that it should prove very useful in control and diagnosis.

During the year 427,000 doses of vaccine, about 52 per cent. of that used last year, were distributed, mainly to Queensland and the Northern Territory. The fall is attributed to the effects of the drought upon movements of stock. Sufficient antigen for the complement test, to test 13,000 animals, was distributed gratis to various laboratories. Twenty-three per cent. of this was for use in Australia and 77 per cent. for abroad, mainly for Kenya and Northern Nigeria, with a small amount for Portugal.

(*b*) Mastitis in Dairy Cattle.—Work has been greatly curtailed, but a restricted number of problems has received some attention. Further attempts at more efficient chemotherapy of staphylococcal infections of the udder have followed the unsatisfactory results with penicillin, streptomycin, and aureomycin. During the year further trials with aureomycin yielded no better results than before; the low proportion of cures, 10-30 per cent. is regarded as unsatisfactory. Even when treatment was repeated with two doses of 420 mg., the infection was eliminated from only three out of eight quarters. Furacin (5-nitro-2-furaldehyde semicarbazone), which had been reported favourably upon abroad, also failed to eliminate infection.

During another unsuccessful attempt upon staphylococcal mastitis with penicillin, it was found that the potassium salt of crystalline penicillin G was very irritant to the udder and caused multiple fibrin clots in the milk.

Another attempt to eliminate *Streptococcus agalactiae* infection from a herd by "whole-herd treatment" with penicillin failed in its primary objective although, as on previous occasions, the streptococcal count was in many cases greatly reduced temporarily.

(*c*) *Brucellosis in Cattle.*—After experiments some years ago by the Organization, field trials of "strain 19" vaccination in calves were made by State authorities and these indicated the value of the standard method of injecting 5.0 ml. of vaccine under the skin (subcutaneous vaccination). The abortion rates in vaccinated heifers, during the first pregnancy, was reduced to about one-sixth or one-eighth of that in unvaccinated heifers on the same properties; the abortion rates among vaccinated heifers in a later pregnancy also appeared to be low but the constant sale and resale of cattle in private herds renders the collection of accurate statistics difficult.

Since 1948 a series of experiments under controlled conditions has been in operation in the Division of Animal Health and Production, in which were used both the standard subcutaneous method of vaccination and a method whereby one-fifth of the usual dose of vaccine is injected into the tip of the tail (intracaudal method). It has already been reported that the results of a first exposure to infection during pregnancy in the second year after vaccination confirm the efficacy of vaccination as a means of reducing the number of abortions; the intracaudal method was at least as effective as the subcutaneous.

During the past year, cattle, which had proved to be completely immune in the first test, which failed to abort, and were free from infection at the time of calving, were submitted to a second exposure to infection during pregnancy in the third year after vaccination. The beneficial effects of vaccination were still strongly evident, as no animal aborted and relatively few showed evidence of infection. Those which had originally been vaccinated intracaudally were as resistant as those vaccinated subcutaneously. In addition, a group was exposed for the first time, during pregnancy in the third year after vaccination, and reduced abortion rates of a similar order in animals vaccinated by either method was observed.

The work over these years emphasizes the valuable effect of "strain 19" vaccination in reducing the economic losses resulting from brucellosis, but it should be realized that many vaccinated cattle, which are naturally exposed to infection, may, although protected from abortion, liberate virulent *Br. abortus* when they calve, and are thus capable of spreading the infection among non-vaccinated cattle.

The practical advantages associated with the intracaudal method warrant a more extensive trial throughout Australia. Its adoption would reduce the expenses of vaccination and minimize the cold storage space which is required for keeping bacteria of the "strain 19" vaccine alive before use.

In addition to work on the experimental herds on our field stations, laboratory investigations on a special milk test have been continued. The test is chiefly of academic interest, but it is likely to find a useful practical application especially in countries where plans for the complete eradication of brucellosis are being implemented.

(*d*) Haematuria vesicalis *in Cattle.*—Work on this problem has been limited to (i) synthesis of several unobtainable compounds required in the study of methods for estimating amino-phenols in bovine urine, and (ii) synthesis of various quinonoid derivatives of tryptophane required in testing an hypothesis that the disease might be related to sensitization of the bladder to quinonoid derivatives of amino-phenols excreted in the urine.

3. Internal Parasites.

(*a*) *Epidemiology of Parasitic Gastro-enteritis of Cattle.*—These studies were continued at the Veterinary Parasitology Laboratory, Brisbane, and herds at Dayboro, Maleny, and Oakey, Queensland, and Armidale, New South Wales, have been under observation. A severe drought prevailed throughout this area during the late winter, spring, and summer of 1951-52, and observations had to be discontinued throughout part of this period as the cattle were too weak to handle. Much of the information already published on the fluctuations among the populations of the various helminth species and on treatment periods has been confirmed. Despite the drought conditions, very heavy infestations occurred in one herd owing to the overcrowding of animals on the only green feed available in gullies and on creek banks.

These trials have indicated that *Bunostomum phlebotomum* is capable of surviving in areas with a mean monthly minimum temperature as low as 44° F., and a mean monthly maximum temperature as low as 68° F., but does not appear able to exist where the average annual rainfall is 25 inches or less. *Cooperia oncophora* and *Nematodirus* spp. have similar fluctuations in egg output to the other species. Infestations of both species reach their maximum in the winter and early spring and usually when calves are only three-four months old. Infestations of *C. oncophora* may persist for many more months but those of *Nematodirus* spp. are eventually completely eliminated and are rarely present in calves older than 6 months. The distribution of these two species indicates a delicate tolerance to small changes in temperature. Both are prevalent on the higher lands of the Darling Downs where the elevation is 1,300 feet or more, whereas, on the coast, *Cooperia oncophora* is confined to isolated areas of high elevation and *Nematodirus* spp. are extremely rare.

Observations also showed there may be great differences in the types of climate favorable to *Haemonchus contortus* and *Bosicola radiatum.* The latter attained serious proportions among the Oakey herd, whereas the former was never present except in very small numbers.

(*b*) *Faecal Examination as a Measure of Helminth Infestation.*—A large number of values for the daily faecal output of young cattle is now available and is being given statistical examination. These values should supply a correction figure to permit a comparison of egg count between animals of different weights and of different faecal outputs.

(*c*) *Liver Fluke* (Fasciola hepatica).—Specimens of fluke snails from various parts of Australia have been examined and snails from South Australia, Queensland, New South Wales, and Victoria all conform to a single species, usually called *Simlymnaea brazieri,* but more correctly *S. subaquatilis.* The position in Tasmania is still obscure: the snails received as fluke snails were *Lymnaea papyracea.* This species also occurs commonly in Victoria and can be easily confused with *S. subaquatilis.* There is no evidence that it is an intermediate host of *F. hepatica.*

Attempts have been made to culture *S. subaquatilis* in large concrete aquaria. Colonies of snails have developed satisfactorily and infestation of large numbers of snails with the miracidia of *F. hepatica* has been successful. The metacercaria will be used by officers of the McMaster Laboratory for anthelmintic studies.

(*d*) *Amphistomes of Cattle.*—Work on the life histories of *Ceylonocotyle streptocoelium* and *Paramphistomum ichikawai* has been continued. The life histories of both species are very similar, but the developmental period of *P. ichikawai* in the snail intermediate host is much shorter than that of *C. streptocoelium.* At 20° C. sporocysts of the former appeared ten days after infection and those of the latter, twenty days after, and whereas cercariae of *P. ichikawai* were secreted after 41 days, those of *C. streptocoelium* were not seen until 63 days.

The morphology of the immature stages of both species was studied in detail. There is little difference between the eggs, miracidia, sporocysts, and rediae, but the cercariae are readily distinguished by their excretory systems. Penetration of the snail by the miracidia occurs through the mantle cavity into the heart cavity.

There is evidence that snails when infected even by a single miracidium will continue to produce cercariae as long as they live. This is related to the development of daughter rediae, but this apparently occurs only when the snails are on a high plane of nutrition. Snails infected with a single miracidium in the laboratory produced 649 to 1,748 cercariae and were still infected when they died.

C. streptocoelium reached maturity in sheep and cattle in 48 and 52 days respectively after the metacercariae were fed. This period for *P. ichikawai* in sheep was 49-51 days. Metacercariae excyst in the duodenum and the young flukes migrate to the rumen within three weeks.

There is some evidence of a rhythm in egg production, periods of egg production alternating with periods when no eggs can be detected in the flukes or in the faeces. Cessation of egg production appears to be associated with testicular degeneration.

(*e*) *The Administration of Anthelmintics to Cattle.*—Studies on reflex closure of the oesophageal groove of cattle have been completed and it was found that in calves up to fourteen months old a solution of 5-10 per cent. sodium bicarbonate caused closure in approximately 90 per cent. of the animals on which it was tested. Sodium chloride also brought about this result but was not as efficient as sodium bicarbonate.

Further observations on the value of glucose as an indicator of the closure or otherwise of the oesophageal groove show that, when glucose is given directly into the rumen or abomasum through fistulae, abomasal injection results in a maximum increase in blood glucose in 60-120 minutes after treatment and an increase is maintained for from two-four hours, whereas with ruminal injection no increase in blood glucose is observed for at least three hours after treatment.

In calves drenched with 60 ml. sodium bicarbonate followed by 50 gm. glucose and congo red the mean increase and range in blood glucose was as follows:—

Location of Dye.	Blood Glucose.	
	Mean Value.	Range.
	(mg.%)	(mg.%)
Abomasum only	57.5	16.9–150.7
Abomasum chiefly	37.4	16.6– 73.2
Rumen only or chiefly	7.4	2.8– 15.2

These values correspond very closely to those observed when glucose was injected directly into the abomasum or rumen.

(*f*) *Hydatids in Cattle.*—An investigation into the high incidence of hydatids in cattle in coastal Queensland has been completed. Cattle play little if any part in the maintenance of *Echinococcus granulosus* as almost all the cysts found in cattle are sterile. Examination of a limited number of dogs failed to produce any evidence that dogs were implicated. It is apparent that the parasite is being maintained by the dingo and wallaby and that cattle become infected by grazing areas contaminated with the faeces of the dingo.

(*g*) *Differentiation of the Infective Larvae of Cattle Strongyles.*—Early in the establishment of the Veterinary Parasitology Laboratory, attention was given to the differentiation of the infective larvae of cattle strongyles and the work subsequently carried out on the epidemiology of parasitic gastro-enteritis and on field tests of anthelmintics was based on this. As, however, very little information is available in the literature on the differentiation of infective larvae, it was decided to continue this work with the object of providing information enabling a rapid diagnosis of the various larvae. Larvae of *Haemonchus contortus, Ostertagia ostertagi, Trichostrongylus axei, Bunostomum phlebotomum, Cooperia punctata, C. pectinate, C. oncophora, Nematodirus spp., Strongyloides papillosus,* and *Bosicola radiatum* have been differentiated mainly on body length, tail length, and certain head characters.

(*h*) Haemonchus contortus *in Cattle and Sheep.*—The majority of female *H. contortus* in sheep have a well-developed tongue-like process overhanging the vulva, whereas in the majority of females from cattle this process is reduced to a small rounded knob. Infective larvae from cattle are longer, more robust, and have a much longer and more whip-like tail than infective larvae from sheep. Furthermore, whereas sheep may be readily infected with larvae from cattle, cattle are resistant to larvae from sheep. These differences postulate the possibility that *H. contortus* of cattle and sheep may comprise more than one species.

Examination of adult males and females from these two hosts did not show any differences of specific value. Extensive measurements of infective larvae and their respective tail lengths have been made and the establishment of the progeny of single females in the two hosts is being attempted to ascertain the degree to which the vulval flap may vary. Experiments are also under way to ascertain whether the differences in size of the larvae are a result or otherwise of host influence.

(i) *Intermediate Host of* Moniezie benedeni.—Examination of oribatid mites from cattle pastures revealed cysticercoids in only one species, at present undetermined but belonging to the genus *Oribatula.* Mites of this species were fed to a worm-free calf and a specimen of *M. benedeni* was subsequently obtained. Cysticercoids were also present in this mite collected from a sheep pasture and were probably those of *M. expansa.*

4. Cattle Tick.

(*a*) *Chemical and Biochemical Studies.*—(i) *Bioassay Tests.*—*In vitro* tests are carried out on adult female ticks for preliminary screening of insecticides and other toxicological studies to save expensive, full-scale testing of materials in cattle dips. During the year tests were conducted on some of the newer chloroinated insecticides and some 50 other compounds. Chemicals tested included toxaphene, aldrin, dieldrin, parathion, "Menthachlor", several compositions containing BHC, and other compounds, such as sulphones, sulphonates, indanediones, carbinols, xanthates, ethers, and iodine wetter complexes. Dieldrin was found to be one of the most promising compounds, a concentration of 0.032 per cent. being required to kill 50 per cent. of the adults, indicating that it is several times more toxic than aldrin. BHC kills 50 per cent. of the adults when the concentration of the gamma-isomer is 0.002 per cent. "Menthachlor" (chlorinated phellandrene) appears a promising material, and the sulphones, sulphonates, and indanediones are worthy of further investigation. It has been established that parathion remains stable for two years in slightly acid solution, but work on this material has been discontinued because of its high toxicity to man and animals.

(ii) *Attempts to Improve Toxicity of DDT.*—A number of experiments were conducted to find means of increasing tick kill with DDT. Research has not yet disclosed a synergist for use with this preparation, but it has been found that the solvent used in emulsion concentrates has an important influence on toxicity. DDT is most toxic to ticks in "Sovacide"-based emulsions, whilst kerosene-based emulsions also rank very high. Better penetration of DDT into ticks resulted when their cuticle was damaged by certain phosphates, acids, and alkalis incorporated in the dipping fluids.

In experiments where ticks were kept at constant temperatures, it was found that tick mortality from DDT increased as the temperature decreased. This indicates that DDT dips would be more efficient if applied in early morning or late evening.

(iii) *Loss of Efficiency of BHC Dipping Fluids.*—Technical BHC consists of five isomers of which the most toxic is the gamma-isomer. It has previously been assumed that the five isomers would remain in a dip in the same ratio to one another as they were in the original technical BHC. Consequently, methods of analysis which involved the dehydrochlorination of all the isomers were considered satisfactory. Recently some samples of dips in which analysis by dehydrochlorination had indicated a high BHC content were found in bioassay tests to have no toxicity to cattle tick. Study by adsorption chromatography showed an almost complete loss of gamma-isomer from these samples. It is not known whether the loss occurred in the dipping vat or while the samples were standing in the laboratory, but the result has important implications.

(iv) *Resistant Strains of Ticks.*—An investigation into the death of cattle in the Rockhampton district revealed that the concentration of BHC in the dips had been raised to levels toxic for the cattle, but not the ticks. This strain of tick has developed a tolerance enabling it to survive a gamma-isomer concentration of about 200 times normal; it is also resistant to toxaphene and slightly resistant to DDT. Tests are in progress to determine whether an arsenic-resistant strain exists in New South Wales, where some cattle have been dipped nine times at fortnightly intervals, and still not been declared clean.

(v) *Other Investigations.*—In field spraying trials satisfactory kills of ticks on cattle were obtained with 0.25 per cent. toxaphene and 0.025 and 0.05 per cent. dialdrin. The latter compound appears to combine excellent residual effect, comparable with DDT, and high toxicity at low concentrations.

Examination of the relation between the alpha- and amma-isomers of BHC has shown that the alpha-somer tends to neutralize the toxicity of the gamma-somer. In formulations usually employed, however, his does not seriously affect the toxicity.

Attempts have been made to identify the compounds nto which DDT is resolved by the tissues of normal icks after absorption, so that they may be compared with the corresponding metabolites in a DDT-resistant strain.

(*b*) *Biological and Ecological Studies.*—(i) *Survival of Larvae and Adults in the Field.*—Early morning observations led to experiments with natural and artificial dews to determine whether the larvae could utilize the moisture from dew, and thus resist desiccation. It was confirmed that dew falls lengthened life, and larvae have been found to gather round and imbibe a drop of water placed on the outside of gauze tubes in which they were enclosed. Additional water is available to larvae in the field, even in time of drought, in the form of an exudate from certain green grasses.

Experiments with standardized supports, shaded and unshaded, showed that larvae hatching in them lived longer in the shade.

Birds of two native species have been observed to take ticks off cattle. Species of ants of the genera *Iridomyrmex* and *Aphaenogaster* have again been observed taking adult ticks which had dropped in a natural manner. A common wolf spider also took a tick dropped near its hole. Further work on survival of adult ticks awaits an improved technique of tracking the ticks (e.g., use of a Geiger counter).

(ii) *Distribution of Tick Larvae in a Paddock.*—An uninfested 100-acre paddock was stocked with six infested animals and a heavy infestation built up in spite of the low stocking rate. Observations are being plotted for 24-hour periods on the grazing behaviour of the cattle in a rough pasture, using a selected belled animal. In addition to being affected by the habits of the host, distribution of the larvae would be affected by any tendency for the adult ticks to drop off cattle at a non-uniform rate. Collections of ticks which had fallen from stabled cattle were made at four-hourly intervals, and it was found that there was a high drop-off between 6 and 10 a.m. If this applies to cattle in the field, it will be significant in relation to the distribution of larval ticks.

Investigations have been continued on methods of measuring the level of larval infestation of pastures. A year's trial in rough grazing has shown that a practical method of sampling is the counting of the larval ticks picked upon a pair of tightly fitting white duck trousers worn on the legs of the observer. This method is, however, of little use in very short grass. The maximum number of larvae picked up in 50 yards was 420, but few counts exceeded twenty. Tests are now proceeding to determine the rate at which larvae drop off after attachment, in relation to distance travelled, and the impregnation or otherwise of the fabric with bovine odour. Work is proceeding on a different kind of sampler to be wheeled in front of the observer. This may prove more efficient in some respects than the trouser or blanket samplers, but may be less manœuvreable, than the former.

Larvae have been encountered on an area 33 days after the passage of a bush fire, and one adult male was also picked up. The repeated weekly or fortnightly observations have revealed seasonal variations in the feeding habits of the cattle, for example, between creek banks and ridges, and emphasize the wide seasonal variation in grass length and density. Attempts are being made to record grazing intensity on the areas sampled to further the understanding of their behaviour on tall vegetation. Observations have also been made on the heights to which larvae will ascend artificial supports.

(iii) *Host Preference.*—Ticks have been recorded from goats for the first time in Australia. Horses running together with cattle have shown very few attached ticks, and sheep none. Tick larvae have been observed to leave an unacceptable host, a guinea pig, and later to ascend the walls of the cage and search for suitable hosts in a normal manner. This suggests that non-bovine occupants of a paddock could spread larvae.

5. PRODUCTION IN DAIRY-CATTLE HERDS.

(*a*) *Development of Hybrid Dairy Cattle.*—The crossbred dairy herd now contains 53 head, including seventeen females of the Red Poll, Jersey, Friesian and Illawarra Shorthorn breeds. There is also one animal with 12.5 per cent. Zebu; one with 18.75 per cent. twenty with 25 per cent.; one with 37.5 per cent.; six with 50 per cent.; one with 75 per cent.; and two full-blood Zebus.

Of the 25 per cent. Zebu junior two-year-old heifers, have completed their first 270 days of lactation with mean production figures of 3,606 lb. milk, 4.7 test, and 167 lb. butterfat. This compares with 5,316 lb. milk, 4.2 test, and 226 lb. butterfat for the first 270 days of lactation of nineteen British-bred heifers. No further records have become available for 37.5 per cent. crossbreds.

Of the 25 per cent. Zebu junior two-year-old heifers, five of Jersey x Zebu breeding averaged 4,029 lb. milk, 4.9 test, and 202 lb. of butterfat, whilst four of Red Poll x Zebu breeding averaged 4,631 lb. milk, 4.5 test, and 204 lb. butterfat. No Friesian x Zebu crossbred has so far been tested. The remaining three crossbreds were derived from ordinary grade dairy cattle. Their production was extremely low, namely, 1,214 lb. milk, 4.4 test, and 61 lb. butterfat. Two of the Red Poll crossbreds have since commenced their second lactations as junior three-year-olds and have reached a peak of 45 lb. milk daily, which figure has in no way been approached by Jersey crossbreds on their second calf.

The crossbred cattle have a low ceiling of total milk production although the percentage of butterfat is comparable to that of the British breeds. In an endeavour to break through this low ceiling a Sindhi x Jersey bull having 75 per cent. of Sindhi blood and backed by good milk production has been imported from America. He will be mated with British-bred cows of proved high production, and with the best of the crossbred females at present in the herd. His acquisition is a most important step forward in the current breeding programme.

(*b*) *Physiology of Milk Secretion.*—During the year the following aspects have been studied:—(i) factors influencing udder capacity, (ii) measurement of intramammary pressure, (iii) relationship of intramammary pressure to milk ejection and udder capacity, and (iv) variation in residual milk and its relationship to total yield. A progressive decline during the course of lactation, in the maximum amount of milk which the udder will hold has been established. It is also fairly well established that this decline is approximately proportioned to the decline in secretion rate, and that the time intervals at which partial or complete inhibition of secretion sets in, although varying greatly from cow to cow, are independent of the stage of lactation. It should now be possible to rationalize the differences in milk secretion curves between cows. A simple apparatus has been constructed for measuring the intramammary pressure and some preliminary observations have been made on the changes in pressure associated with milk ejections. A study has been made of the effect of varying the total milk yield by varying the interval since previous milking, and of the influence of this upon the amount of residual milk which is retained in the udder and is extractable only after injection of pituitary extract. It has been found that there is a positive correlation between total yield and residual milk; on the average for every 10 lb. increase in total yield there is an increase of 1½ lb. in the amount of milk retained. This finding has important implications and makes it likely that the interpretation of data purporting to measure the inhibition of secretions caused by long intervals between milkings may have to be greatly modified.

The identical-twin herd is being built up and some are coming into lactation and will now be available for study.

A trial on sixteen cows was carried out to test a claim that feeding of a supplement of *Penicillium* residue from penicillin production increased fat content of the milk. The trial lasted five weeks and yielded no evidence in support of the claim.

6. Investigation of Beef Production in Australia.

(*a*) *Survey of Beef Cattle Production.*—The survey was concluded during the year. The first interim report on beef cattle production in northern Australia was published and a limited circulation made during the year. The second interim report has been prepared and work on the final report was started.

(*b*) *Studies on the Bovine Skin.*—The collection of skin samples was continued as opportunity offered and these are being studied with a view to determining the correlation of characters to adaptation of individuals to tropical climates.

(*c*) *Beef Cattle Feeding Investigations.*—No further studies on the topping off of beef cattle by stall feeding have been made during the year. Information and data on the feeding standards used for beef cattle in the United Kingdom and in the United States of America have been compiled and discussed in a report which has been submitted for consideration of the possible adoption of similar standards by the cattle industry of Australia. A report on the stall-feeding experiments conducted in collaboration with Mr. G. H. Hooper at "Talbingo", New South Wales, has also been prepared.

(*d*) *The Feeding of Stud Beef Cattle.*—Complete nutritional records have now been collected during a three-year period at one Hereford stud. The data for food consumption and body-weight changes have been derived from 65 animals including males, females, and steers of various ages. Similar observations on a Polled Hereford stud have been temporarily discontinued after some three years' work, owing to its transfer to a more distant property. The rations, and quantities given to cattle of different weights and ages, have been based on scientific feeding standards. The results, as indicated by the success of these studs in the show ring and in carcass competitions, have shown clearly that feeding standards based on British and American research are fully applicable under Australian conditions. In addition, the information derived from this work can be used as a guide in further studies on stall feeding for commercial beef production.

(*e*) *Beef Cattle Investigations in the Southern States of Australia.*—Nine of the twelve centres, which were to be established with funds provided by the Australian Meat Board, have now been developed by the Departments of Agriculture in New South Wales, Victoria, South Australia, Western Australia, and Tasmania. An officer of the Division of Animal Health and Production is assisting the Australian Animal Production Committee's Technical Sub-committee on Beef Cattle, by correlating the work and the data derived from the several States. Valuable information is now accumulating on animal growth curves, grazing on improved pasture, native pasture and crops, supplementary feeding with hay during periods of static, or falling body weight, and on carcass appraisal.

IX. ENTOMOLOGY.

1. General.

The Division of Entomology is engaged in a programme of research on insect pests and their control, including those insects which are vectors of virus diseases of plants or animals, and on the biological control of weeds.

Research on insects affecting animals is done in co-operation with the Division of Animal Health and Production, and is reported more fully in Chapters VII. and VIII.

The Division of Forest Products is also responsible for some work on the pests of timber (*see* Chapter XIII.).

The Wildlife Survey Section is mainly responsible for research on the virus disease of rabbits, and this work is described fully in Chapter X. The Division of Entomology plays a part in these investigations (*see* Section 8 (*d*) of this Chapter).

Work on cattle tick and sheep blowfly is reported in Chapter VIII., Section 4 and Chapter VII., Section 18, respectively.

Division of Entomology.—The head-quarters of the Division are at Canberra. The Division is also represented at Yeerongpilly, Queensland, where much of the work on the cattle tick is undertaken and a small station at Rockhampton has been set up so that the ecology of the cattle tick can be more easily observed. Officers in Western Australia at the Institute of Agriculture, Nedlands, are continuing work on the red-legged earth mite; the lucerne flea is also to be studied from this centre. A biological control station has been set up in Sydney with the primary object of receiving parasites of the Queensland fruit fly, so as to facilitate their introduction from Hawaii. Some observations on locusts and grasshoppers are made from the field station at Trangie, New South Wales. There is also a small station at Bright, Victoria, now terminating a programme of ecological research with insects introduced some years ago against St. John's wort.

The main emphasis in the Division's programme is not so much on direct attack against particular pests as on the elucidation of fundamental facts about insects. In many of the projects which involve specific insect pests, the line of investigation generally includes ecology, or the relation between the insect and its environment. In this policy the Division is following a trend which is evident in other parts of the world, namely a shifting of the emphasis from widespread use of insecticides to the idea of finding weak links in the insect's defence so that it can be attacked in the most efficient manner. Within recent years, new and highly toxic insecticides have revolutionized pest control, but in some instances they have created problems by destroying the balance of nature. For example, treatment against the earth mite may favour an associated pest, the lucerne flea, by killing its natural enemies.

There have been many requests from primary producers' organizations for work on the biological control of certain weeds. The Division has not the staff available to undertake further investigations in this field, and attempts are now being made to increase the staff of this Section.

The Division has continued working in co-operation with the Wildlife Survey Section on the insect vectors of the virus disease myxomatosis of rabbits.

Co-operative work on the Argentine ant with State Departments in Western Australia and New South Wales has produced very satisfactory results. It is now considered that no further useful information could be obtained from additional small-scale tests, and that a large-scale test such as an eradication campaign in Sydney, is needed to prove definitely tht eradication is possible. It is hoped that such a campaign can be arranged during the coming summer.

Progress has been made in the two new fields of research, pasture caterpillars and stored-products pests, opened up last year.

2. Insect Physiology and Toxicology.

(*a*) *Digestion of Wool by Insects.*—Further progress has been made in elucidating the mechanisms involved in keratin digestion and it has been established that a striking feature which keratin-digesting insects have in common is the high reducing capacity of their midgut juices. Closely related insects, unable to digest keratin, do not maintain these highly reducing conditions in their digestive tracts. The reducing conditions cause the rupture of the resistant disulphide bonds of keratin cystine (with the production of cystein residues) and permit proteolytic enzymes to continue the degradation of keratin.

Larvae of the clothes moth *Tineola,* which have very alkaline digestive juices, degrade portion (but not all) of the cysteine still further with the production of hydrogen sulphide, pyruvic acid, and probably ammonia, this degradation being brought about by the presence in the midgut of a cysteine desulphydrase. Many common inorganic poisons fed to clothes moth larvae are detoxified by the formation of insoluble metal sulphides resulting from interaction with the hydrogen sulphide.

Carpet beetle larvae (having neutral but highly-reducing digestive juices) do not degrade cystine further than cysteine, almost all of the latter being excreted. Consequently sulphides are not formed when appropriate metals are fed. However, undissociated metal-cysteine complexes are produced (visible in the digestive tract in the case of the brown cobalt complex), which also serve to detoxify some inorganic poisons.

(*b*) *Moth-proofing Tests.*—Excreted uric acid and fabric weight loss have been compared as criteria for assessing moth-proofness, using wild stocks of larvae as well as larvae from ten and twenty generations of inbreeding. Ninety test samples of Australian and American fabrics were examined. Inbreeding did not reduce variability of results and it was further concluded that the uric acid was not sufficiently less variable than the currently used fabric weight loss method to warrant the adoption of this more complex procedure.

(*c*) *Uric Acid Metabolism.*—This work has concentrated on the analysis and separation of uric acid from the tissues and excreta of grasshoppers, as a preliminary to an investigation of uric acid synthesis with the aid of C^{14}. A method of analysis involving chromatographic separation followed by differential spectrophotometry has been developed. Recovery of uric acid from the excreta has been complicated by anomalous solubility effects, but a satisfactory method is now in sight. Urea analysis has been applied successfully to grasshopper excreta.

(*d*) *Insect Muscle Biochemistry.*—A kinetic study of the magnesium-activated apyrase of insect muscle has been extended and completed. This has involved the establishment of the temperature-velocity relationship of the enzyme and the determination of dissociation constants for the complexes formed by the enzyme with its two substrates ATP and ADP.

Work on the separation from insect muscle of myosin-adenosinetriphosphatase, myokinase, and pyrophosphatase has also been completed.

(*e*) *Cuticular Proteins.*—The water-insoluble proteins of insect cuticle have been shown to have properties very similar to those of the water-soluble proteins. Such differences as do appear can be accounted for by the mechanism of hardening (or tanning) which involves the formation of cross linkages by reaction between the free amino-groups of the protein chains and *o*-benzoquinones. It is the presence of these cross linkages which renders the protein insoluble in water.

The structure and properties of the hardened (tanned) protein have been investigated. Previously it had been shown that the presence of an added *o*-dihydric phenol is not essential for an insect cuticular protein to become tanned in the presence of the enzyme polyphenol oxidase. The mechanism of the tanning reaction, the origin of the *o*-dihydric phenols (precursors of the *o*-benzoquinones), and the role played by glutamic acid and tyrosine in the tanning (hardening) process have been studied. The tanned protein (sclerotin) is quite different from melanin.

(*f*) *Insect Haemolymph.*—An investigation of the pigments responsible for the green colour of the haemolymph of a number of insects has shown that there are present both blue and yellow pigments, which together give the green colour. In many insects the blue component is a chromo-protein, the prosthetic group of which is the bile pigment mesobiliverdin. However, in one insect the blue component had properties resembling those of the anthocyanins of plants. In all insects examined the yellow component was a carotinoprotein, the prosthetic group being β-carotene or xanthophyll or both.

Work has continued on the differences in the composition of the larval, prepupal, and early pupal haemolymph of *Calliphora* spp. (blowflies). Much time has been devoted to the develoment of a method for the quantitative paper chromatography of amino acids.

(*g*) *Influence of Nutrition on Reproduction.*—The utilization of 33 carbohydrates by the Australian sheep blowfly (*Lucilia cuprina*) has been studied. It has been demonstrated that without a supply of a suitable carbohydrate, this species is unable to produce eggs even if adequate protein is available.

Some 150 diets have been studied to determine what nutritive factors are required for egg maturation. With sugar and purified casein, both magnesium and calcium are necessary dietary constituents. Antagonism exists between magnesium and potassium. The mixture of ten amino acids essential for rat growth is also adequate for egg maturation, although development is slower than when casein is supplied instead. Fats and vitamins do not appear to be necessary.

When suitable carbohydrate is available, ground snails, snail mucus, or the fresh faeces of horse, cow, fowl, and rabbit each permitted egg maturation. These studies are throwing light on the factors influencing the fecundity of the sheep blowfly under natural conditions.

(*h*) *Colour Change in a Grasshopper.*—The grasshopper *Kosciuskola tristis,* which inhabits the Australian Alps, undergoes a colour change from olive-black at night and on cold overcast days to blue on exposure to sunlight. This colour change is due entirely to temperature and is not influenced by light, background, crowding, or humidity.

The colour changes are due to movement in opposite directions of blue and brown pigment granules present in large numbers in the hypodermal cells. The response of each hypodermal cell is independent of that of surrounding cells.

This is the only known example of rapid colour change in the Acrididae, of colour change in response solely to temperature, and of colour change due entirely to independent effectors.

3. Biological Control.

One of the most important activities of the Division of Entomology since its inception has been the biological control of weeds and of insect pests. Current research is limited to only a few such problems, but it is hoped that staff will be available to attend to others in the near future. Successful biological control of a weed or insect pest is, of course, much more satisfactory than repeated chemical control. The idea has great popular appeal, and the Division cannot undertake more than a small proportion of the work it is requested to do in this field.

(*a*) *St. John's Wort* (Hypericum perforatum *var.* angustifolium).—(i) *Ecological Studies at Bright, Victoria.*—These studies were commenced at Bright in 1948 in order to assess the effectiveness of *Chrysomela gemellata* Rossi and *C. hyperici* Forst. as controls of St. John's wort and to obtain information which may be useful for future experiments in the entomological control of weeds. This investigation has been completed except for some routine observations which are being continued to round off the data available.

The conditions prevailing in the Bright district during this study period, generally speaking, have been near the limit of tolerance of both *C. gemellata* and *C. hyperici.* The total area favorable to multiplication of the insects comprises only a small part of the area which has been successfully colonized by the weed. For example, neither insect has been able to colonize the timbered areas infested by St. John's wort. Only in small treeless areas adjoining densely timbered country infested by the weed have the insects been able to control it effectively. The timbered area has acted as a damping factor to population fluctuation, enabling the insects to persist in moderate numbers.

Both species have poor powers of dispersal and relatively poor ability to multiply, which has been the primary cause of their failure although adverse physical conditions have contributed. Both species are able to multiply within a few years in the most favorable sites to a density high enough to cause complete defoliation of the host plant, which usually dies out. In this way they destroy their food and reduce their protective cover and thus greatly limit their own numbers. A high proportion of the mortality is caused by frost and predation, which operate in an intensified manner because of the removal of the protective cover provided by the foliage of the host plant, but many succumb to starvation. After complete defoliation of the weed in an area the surviving beetles migrate elsewhere in search of more food. Their desertion of the site gives the host plant a chance to recover by regeneration from seed. It is frequently allowed to recover almost completely before beetle numbers become sufficiently high to defoliate again. This is due to the operation of numerous environmental factors unfavorable to the insects as well as their poor mobility and slow rate of increase.

Where other wort-controlling agencies are lacking the insects have caused the host plant to fluctuate violently in density in both space and time without producing a great overall reduction in quantity. By destroying stands of the weed in the areas where the soils are capable of growing a dense pasture, insects have paved the way for successful wort control by other factors, e.g., shade-producing herbage and grazing animals. Such areas virtually cease to provide habitats for the insects after the original stand of St. John's wort is destroyed.

(ii) *Liberation of* Chrysomela *Species.*—The collection and distribution of beetles late in 1951 was mainly restricted to *C. gemallata.* Valuable assistance was again rendered by the Victorian Department of Lands and Survey in collecting beetles, and by the New South Wales Department of Agriculture and the Eastern Riverina and Mid-western County Councils in making liberations and progress reports after liberations.

Liberations were made in New South Wales in the following districts:—Tumbarumba (72,000 beetles), Tumut (70,000), Tuena (315,000), Nullo Mountain (210,000), Capertee (70,000), Sodwalls (70,000), Coolah (140,000), and Cullen Bullen (70,000). In the Tuena district, the insects are making satisfactory progress following liberations over the past three years.

(*b*) *Heliotropium europaeum.*—The prospect of the successful biological control of this annual weed has not been considered to be very promising since a recent survey in the western Mediterranean region (where it is native) showed that its associated insect fauna is, generally, very polyphagous. The only insect that seemed worth more detailed investigation was *Longitarsus albineus.* At the request of the Organization an entomologist of the Commonwealth Insitute of Biological Control studied the biology of this insect in Italy and the results of this investigation strongly suggest that *Longitarsus albineus* cannot effectively control the weed. Since the earlier survey was made in parts of the natural area of distribution climatically similar to the infested areas in Australia, it now seems improbable that safe and efficacious insect enemies of *H. europaeum* exist. The investigation, therefore, is being pursued no further.

(*c*) *Cabbage Moth,* Plutella maculipennis.—During the year parasites of this pest have been imported from Italy, and cultures of them established at the Canberra laboratories. These parasites are *Angitia tibialis, Daidromus collaris,* and *Apanteles plutellae.*

There is some doubt as to whether the "*tibialis*" specimens are in fact distinct from *A. cerophaga,* which is already established. The material available cannot so far be separated into two species, and specialists are not in agreement on the matter. We may be dealing with two species, or one or two races of a single species. Nevertheless, the reputed *A. tibialis* has not previously been imported into Australia.

As a strain of *D. collaris* received several years ago from New Zealand does not appear to be establishing well in Australia, a new strain from Italy was imported, cultured, and distributed during this season. It is not yet known whether this has been followed by improvement in the establishment of the species. *Apanteles plutellae* is a larval parasite of *Plutella* that has not previously been imported into Australia. It is an important natural enemy of *Plutella* in Italy, and also reputedly parasitizes *Pieris.* Satisfactory methods of culturing this species have been developed and the species has been generally distributed during the year. Some field recoveries of *A. plutellae* have already been made in the Australian Capital Territory.

The work on *Plutella* parasite introduction and liberation is almost completed, but much remains to be done in assessing the results of the introductions. In areas where field observations have been made (New South Wales and Australian Capital Territory) *Plutella* is now extremely heavily parasitized by *Angitia cerophaga* and general field collection leads to the conclusion that *Plutella* has become greatly reduced in abundance over the last few years.

(*d*) *Cabbage Butterfly,* Pieris rapae.—Work on this species during the year has been concerned predominantly with culturing and liberating the Eurpoean parasite *Apanteles rubecula.* Sufficient have now been distributed to terminate the cultures of this species. Whether this species is permanently established in Australia, and what importance it may have in the control of *Pieris,* are matters for future investigation. *A. rubecula* has, however, already been recovered on several occasions in New South Wales. So far as is known, parasitism of *Pieris* by introduced parasites now generally at a very high level, and there are ndications that *Pieris* is now less abundant than ormerly.

(*e*) *Green Vegetable Bug,* Nezara viridula.—Preccupation with other problems prevented the introuction of parasites of *Nezara* during this year. dvances have been made, however, in our knowledge f the biology and culture methods of *Nezara.* This pecies has been induced for the first time at Canberra o breed throughout the year, instead of entering what reviously appeared to be an obligatory winter diaause. This development is of importance from the oint of view of the subsequent establishment of parate cultures. So far no recoveries have been made f the previously liberated parasite *Trichopoda ennipes.*

(*f*) *Queensland Fruit Fly,* Dacus tryoni.—The work n Hawaii on the biological control of *D. dorsalis* Oriental fruit fly) has made available for the first me a number of important fruit-fly parasites originatng in different parts of Asia and the Pacific. Because f the importance of the Queensland fruit fly as a pest, he time seemed opportune to investigate the possibility f the control of this native species by alien parasites f closely related fruit flies. The work is of importance lso in view of the possibility of the accidental introduction of *D. dorsalis* into Australia.

This investigation has been based on Sydney (which s climatically more suitable than Canberra for this work) at a substation being constructed with the o-operation of the New South Wales Department of Agriculture. The substation will act also as a uarantine station for the importation of beneficial nsect species.

This research is at an early stage and faced with unusual difficulties. The natural hosts of the parasites o be imported do not occur in Australia. Quarantine considerations, therefore, make it necessary to import pecimens in the short-lived adult stage only, and these adults tend to arrive at best in an enfeebled condition. The parasites are difficult enough to culture on *D. dorsalis,* but the establishment of cultures of them in Australia is dependent upon inducing them to parasitize *D. tryoni*—a completely new host—effectively.

So far cultures of three parasites, through the courtesy of the Board of Agriculture and Forestry, have been obtained from Hawaii—*Opius oophilus* (an egg parasite), *O. vandenboschi,* and *O. longicaudatus* (larval parasites). Though cultures of none of these have yet been permanently established in Sydney, it is believed that at least two of them have been successfully bred on Queensland fruit fly. The successful transference of these parasites to Queensland fruit fly is of considerable interest in itself and potentially of considerable importance. That the transference has been effected still requires confirmation.

4. Population Dynamics.

The primary objective of almost all investigations in economic entomology is to find means of reducing the abundance of some pest to a level at which the damage caused is economically negligible. This objective is often, mistakenly, simplified to that of finding more effective ways of killing the pests; for, although the development of better insecticides and better machinery to apply them is extremely important, it is only part of our problem. When pests are destroyed this greatly disturbs the equilibrium which exists between them and their environments; so ultimately we are concerned with the effects such disturbance produces upon the abundance of a pest, and not merely with the mortality produced by the method employed. This system of equilibria is being studied experimentally, using the sheep blowfly as the experimental animal, and it has been found possible, by using this insect and subjecting it to the influence of various kinds of factors, to simulate the characteristics of the population problems presented by different kinds of pests. The experiments have shown that heavy destruction of the insects under certain circumstances leads to their maintenance at much higher population levels than would exist without such destruction; although, naturally, under other circumstances it leads to a reduction of the population. The definition of the conditions under which these effects are produced appears to be leading to conclusions of great practical importance.

Much attention has been given to the re-examination of published data concerning experimental and natural populations. As a result seven quite distinct systems of population regulation have been defined, in each of which there is a different pattern of population growth and maintenance. It has become clear that for the control of any particular pest it is first necessary to understand the interaction between the pest and its environment, for the effects produced by any particular method of control differ greatly with the different systems of population regulation. The results of this investigation already give promise of leading to the more effective control of certain pests with which this Division is concerned.

5. Locust and Grasshopper Investigations.

Extremely dry conditions continued until March, 1952, in the Bogan-Macquarie outbreak area where field studies on the Australian plague locust (*Chortoicetes terminifera*) are centred, thus extending to fifteen months, a drought that had begun in December, 1950. This dry period, following upon a prolonged period of floods and over-moist conditions generally, reduced the population in the outbreak area to the lowest observed at any time since the field investigations were commenced at Trangie in 1939. So scarce had the locust become by April that not more than one or two specimens could be located in many hours of searching. It may be safely assumed that at least the southern portion of the outbreak area will be unable to produce swarms for some years unless re-population takes place from other less severely affected regions.

The plants of *Atriplex nummularia* used in the barrier experiment at Trangie have withstood the adverse conditions extremely well. The barriers are now of sufficient height and density to permit their effect on the locust population to be tested as soon as the latter reaches a sufficient density once more. The rabbit-proof netting was raised on all the barrier plots in August-September, 1951, as a first step towards submitting the barriers to normal grazing pressure. Some barking and defoliation of the lower branches resulted, but, in spite of very high rabbit numbers, this reached serious proportions on only one of the plots. On this plot the netting was lowered again temporarily in late January, in order to safeguard the barrier until the effect of the damage on the health of the plants could be assessed. Practically all the damaged plants are now putting on fresh growth; the mortality has been virtually nil.

For the purpose of testing the effect of the barriers on the locust population, it will be necessary to maintain the pasture in a similar condition inside and outside the treated plots. With this object in view, and as a means also of assessing the effect of stock on the barriers, mobs of several hundred sheep were admitted to the plots for periods of a few days during November and December. The denser pasture within the plots was effectively reduced without appreciable damage to the saltbush. It is not proposed to test the effect of allowing stock unrestricted access to the barriers until the influence of the latter on the locust population has been studied.

Progress has continued in the experimental revegetation of "scalds" as a possible means of reducing the extent of the oviposition habitat in an outbreak area. Particularly striking results have been obtained on a scald planted with *A. nummularia* in rows. There is now a complete, dense cover of annual and perennial pasture plants over the whole area.

Work on the relation between tree density and locust abundance has been interrupted because of the absence of locusts.

6. Cockchafer Investigations.

The investigations on this important group of insects, which includes one of the most serious pests of the better-class pastures in southern Australia, have been curtailed while the principal investigator is overseas.

Rearing of larvae to the adult stage for the purpose of correlating the larval and adult forms of as many species as possible has been continued. By this means it has at last become possible to identify larvae in the large genus *Liparetrus,* several species of which are important as defoliators of eucalypts.

Trapping of adult beetles by means of light traps operated at Canberra and at Trangie, New South Wales, has added to our knowledge of the species occurring in those two areas and of their relative abundance at different times of the year. A small percentage of the specimens caught have shown parasitism by an unidentified insect parasite.

Field and laboratory experiments on the oviposition of unfed females of *Aphodius howitti* suggest that the "primary" oviposition does not normally occur before the adult emerges from the soil, but only after a flight has taken place. The extent of this flight is still unknown, but it may well be quite limited or be replaced by crawling over the surface of the ground under certain conditions.

7. Red-legged Earth Mite Investigations.

(*a*) *Control in the Field with DDT.*—Previous experiments have shown that DDT-superphosphate dusts distributed by farm machinery during the late summer months have not given the efficient control of the earth mite which might have been expected from smaller scale experiments. It was considered that loss of the DDT powder by wind drift was one of the main factors responsible for this. An experiment was therefore performed in which a DDT-superphosphate mixture, mixed at the factory whilst the latter was still damp and before it had formed into granules, was applied by means of a broadcaster in July. A normal dry mixture at the same concentration was used as a comparison. Although much of the drift losses were prevented by this method of mixing, no additional lasting effect was obtained. With each dust an initial kill of 95 per cent. was obtained but the mite population built up to 25 per cent. of that in the untreated areas within two months.

Another factor which may have operated against more efficient control with the dusts was an uneven distribution. It appeared that the new low-volume boom spray equipment would ensure a more even distribution of the DDT and an experiment was commenced using this equipment. Two treatments were applied in late March at rates equivalent to ½ lb. *pp'*-DDT/acre and 1 lb. *pp'*-DDT/acre. The results were again disappointing and were in fact inferior to those with the dusts. A 60 per cent. kill was obtained with the 1 lb. treatment.

It is apparent that a good initial kill of the mite can be obtained by the application of ½ lb. *pp'*-DDT/acre, after the mites have hatched out, either as a dust or a spray, but pre-hatching treatments require heavier dosages. Further inquiries into the factors operating against summer treatments are being made. Sheep grazing on the pastures during the dry periods after application of the DDT may bury much of the insecticide under the soil surface out of reach of the mite and this aspect is receiving attention.

Observations have been made on the effect of aerial spraying of DDT for earth mite control. The results have been extremely good and this method of distribution will no doubt be of great value where large areas of more valuable crop are being attacked.

(*b*) *Experiments with other Insecticides.*—Small-scale experiments with some of the newer insecticides have been made. Sprayed at the rate of ½ lb./acre, dieldrin, aldrin, and chlordane have, one week after spraying, given 94 per cent., 80 per cent., and 50 per cent. kill of the mite respectively. "Phosfone" at the rate of ¼ pint 20 per cent. emulsion/acre has given an 80 per cent. kill. DDT spray used as a comparison, at ½ lb. *pp'*-DDT/acre, gave a 99 per cent. kill and it is apparent that this is still the most efficient insecticide available for this purpose.

(*c*) *Effect of the Mite on Pasture Production.*—The effect of mite attack on an established subterranean clover pasture grazed by sheep is being investigated in a long-term experiment. The first year's results show that by eliminating the mite with DDT treatment a highly significant increase in clover yield is obtained together with smaller increases in some other components and in the total yield of the pasture. Generally there is a small decrease in capeweed yield. There are indications that the effects in the second year will be considerably greater.

8. Insects and Viruses.

(*a*) *Transmission of Lucerne Witches' Broom by Insects.*—A search is being made for vectors of lucerne witches' broom virus other than *Orosius argentatus* (Evans), the species already incriminated. Attempts to establish colonies of four other leafhoppers have been successful with only two, and one of these, *Eurinoscopus punctatus* (Evans), has been shown to be capable of transmitting the disease. However, this species appears to be less efficient than *Orosius* and the search for more efficient vectors will continue. The latent period in both vectors using carrot and sugar beet as indicator plants is of less than 48 hours duration. Shorter periods are now being investigated.

(*b*) *A New Plant Virus Disease.*—Among insects brought to the laboratory from lucerne fields infected by lucerne witches' broom virus were leafhoppers of the species *Nehela torrida* (Evans). This insect transmitted to tomato, carrots, lucerne, and other plants a previously unknown virus with very distinct symptoms. A rather similar disease was seen on carrots at Hawkesbury Agricultural College in an area where *Nehela* was abundant. The most interesting feature of this virus is that it appears to be transmitted from one generation of the leafhopper to the next. This ability to transmit a plant virus through the egg of the vector is known in only four other plant viruses.

(*c*) *Physiology of Virus Vectors.*—It was reported last year that an attempt was being made to determine whether the inability of adult thrips to acquire the virus of tomato spotted wilt was due to a difference in the pH or oxidation-reduction potential or both in the insect midgut. It has now been shown that the conditions in the midgut of larval and adult thrips are almost identical; tests are now being made to determine whether differences in the permeability of the midgut of larvae and adults could account for the differences in ability to acquire tomato spotted wilt virus.

The problem of the mechanism of transmission by aphids of viruses that do not persist in their vectors has so far defied analysis. An attempt has been made to determine whether a study of aphid ingestion would throw light on the problem. Aphids have ingested radiophosphorus incorporated in plant tissues and in sugar solutions. A small fraction (about 0.1 per cent.) of the radiophosphorus ingested is reinjected during a subsequent feed on an isotope-free diet. Short periods of starvation (up to 4 hours) have a marked effect on the ability of aphids to transmit non-persistent viruses, but do not appear to affect the amount of food ingested.

(*d*) *Myxomatosis.*—Although myxomatosis can be spread by contact, insects are mainly responsible for transmission of the disease in the field.

Early work had demonstrated that fleas and several species of mosquitoes could all act as vectors in the laboratory. The Division and the Department of Microbiology of the Australian National University have collaborated in obtaining a clearer picture of the mechanism of transmission by the mosquito, *Aedes aegypti.*

It has been shown that virus ingested with the blood is incapable of causing infections when the mosquito bites subsequently. A mosquito becomes infective only when it penetrates a skin lesion so that the mouthparts become contaminated with virus. There is no latent period and mosquitoes can transmit by interrupted feedings. The probability of a mosquito becoming infective increases with the age of the lesion. It is negligible until the fifth day of the disease and reaches a maximum at the death of the rabbit. The probability of an infective mosquito transmitting the disease is inversely proportional to the logarithm of the time after infection. One mosquito transmitted 29 days after the infective feed. Negative results may intervene between positive transmissions.

Pins stuck into skin lesions transmit the disease in a similar way to mosquitoes. One pin infected six rabbits on subsequent days and one transmitted twelve days after it was infected. Pins stuck into skin distant from a lesion never transmit the disease.

Infective virus was found in mosquito excreta and the gut, but not in other parts of the body. Transovarial infection does not occur.

Transmission of myxomatosis by *Aedes* is therefore purely mechanical and thus differs from the majority of mosquito-borne diseases. Other arthropods probably transmit mechanically also and this suggests that any arthropod that punctures the skin of the rabbit could function as a vector. This is substantiated by the work of the Wildlife Survey Section, which has shown that the rabbit louse and parasitic mites can also transmit the disease in the laboratory. There is no evidence that bush flies are efficient vectors. The relative efficiency of arthropod vectors in the field will depend upon their longevity, flight range, and so on, but particularly upon the frequency with which they feed upon rabbits.

9. Termite Investigations.

The assessment of the termite resistance of timbers, timber treatments, and so on, has continued during the past year, using the standard laboratory colony technique. Altogether 713 test colonies were installed, comprising 296 of *Nasutitermes exitiosus,* 241 of *Coptotermes lacteus,* 162 of *C. acinaciformis,* and 14 of *Mastotermes darwiniensis.* The most significant development has been the successful adaptation of the laboratory colony technique for use with *C. acinaciformis,* which is the most important economic species of termite in Australia. The preliminary studies with *M. darwiniensis* indicate that it may be possible to carry out the accelerated laboratory tests with this species in much the same manner as with the other species of termites.

The materials which have been tested include both native and overseas commercial timbers, treated plywoods, plastics, cable sheathings, and anti-termitic chemicals.

The more important test results were: (i) the addition of 4.8 per cent. crude or 2.0 per cent. gamma-BHC to the glue line of plywoods failed to give adequate protection against termite attack; (ii) the addition of 2.0 per cent. pentachlorophenol or sodium pentachlorophenate to rubber cable sheathing renders it highly repellent and resistant to attack; (iii) plastic cable sheathings of the polythene or polyvinyl chloride type give inadequate protection against attack; and (iv) the timber from plantation-grown exotic pines such as *Pinus radiata, P. laeda, P. patula,* and *P. caribaea,* is all very susceptible to termite attack.

The tests with *C. acinaciformis* showed that ordinarily this species is about twice as voracious as its congener *C. lacteus,* and although the two species exhibit much the same food preferences there are occasional anomalies which prevent results obtained in *C. lacteus* tests from being applied too closely to *C. acinaciformis.*

A limited number of field tests of timbers and preservative treatments are in progress around mound colonies of *C. lacteus* and *N. exitiosus.* A report on the condition of samples in the International Termite Exposure Test after 22 years' service was prepared and forwarded to Madison, United States of America.

The annual examination of the soil poisoning tests showed that both creosote and 5 per cent. pentachlorophenol (both used at the rate of 0.5 gal./cu.ft. soil) have given complete protection against *N. exitiosus* attack for four years; 5 per cent. sodium pentachlorophenate and 10 per cent. sodium arsenite have both given complete protection for three years, and 5 per cent. DDT for two years. In similar tests against *C. lacteus* 5 per cent. pentachlorophenol, 5 per cent. DDT, and creosote have all given complete protection for at least a year.

Approximately 160 series of termites were received for identification during the year. Most of these were collected during termite investigations in north Queensland. Other valuable acquisitions were obtained from Western Australia and New Guinea. This material has provided useful additional records of species distribution, and included two new species of *Amitermes.*

10. Ant Investigations.

(*a*) *Argentine Ant.*—Surveys by State Departments have shown that by June, 1952, the Argentine ant infested 30 square miles of city, suburban, market garden, and orchard areas in Western Australia; 5 square miles in the Melbourne metropolitan area; and 1½ square miles, spread over five municipalities, in the Sydney area. Seven additional infested areas were found in the Sydney area during the year, the largest of which was at Walsh Bay. The maximum spread of the ant from existing infestations was 850 feet during the year and the average spread in the Sydney area was approximately 300 feet per annum, which is the same as in Perth.

Investigations have been carried out in co-operation with the State Departments of Agriculture in New South Wales and Western Australia and the Western Australian Department of Public Health. It has been shown, as convincingly as it can be by relatively small field experiments, that the Argentine ant can be eradicated from residential areas by the application of barrier sprays containing 2 per cent. chlordane, in the form of a grid over the area; it is not necessary to treat inside houses to achieve complete control.

In all experiments in which barrier sprays of 2 per cent. chlordane were applied at a rate of more than 50 gal./acre, complete control was achieved; re-invasion took place in the earlier experiments, but in the 1951-52 experiments all treated blocks were protected from re-invasion by a buffer area treated with 2 per cent. chlordane, thus giving more conclusive results.

At Lidcombe, New South Wales, the application of 2 per cent. chlordane at the rate of 35 gal./acre to an isolated infestation of 9½ acres in April, 1951, did not result in eradication, a few small colonies surviving the treatment. At Alexandria in April, 1952, an isolated infestation of thirteen acres in an industrial area was treated in an attempt to eradicate the ants.

In Western Australia comparative tests were made of the effectiveness of DDT, chlordane, and a mixture containing DDT and chlordane at Subiaco and at Hollywood, a total of 30 acres of residential blocks being treated. The insecticides were applied as barrier sprays in early August (an unfavorable time of the year) and the amount of spray was less than 50 gal./acre. Eradication was not achieved by any of these treatments, but the experiment showed that 2 per cent. DDT sprays were inferior to even 1 per cent. chlordane and that the addition of DDT to the 1 per cent. chlordane did not improve its effectiveness. The areas were re-treated in February, 1952, at the rate of approximately 50 gal./acre and the ants were eradicated from the four blocks treated with 2 per cent. chlordane. The results of the second treatment confirmed the success of chlordane as an eradicant and the imperfect control obtained with DDT. In an experiment at Shenton Park, Western Australia, in November, 1951, residential areas were treated by the application of barrier sprays containing 2 per cent. dieldrin, 2 per cent. aldrin, and 2 per cent. chlordane applied at the rate of 52-54 gal./acre. The results indicate that aldrin and dieldrin are as effective as chlordane.

An experiment was begun at Albany, Western Australia, in January, 1952, to study methods of control of the Argentine ants infesting swamp areas covered by a dense growth of *Psoralia pinata*.

The investigations so far have shown that the treatment of individual household blocks is ineffective, as re-invasion always occurs, sometimes within a few weeks, from adjacent untreated areas. It is evident that eradication is possible but only on a large scale and under unified control. The next step in this work is to attempt eradication from the whole of an isolated infested area, such as that in Sydney, so that the methods evolved can be properly tested. It is hoped that this can be done soon.

(*b*) *Meat Ant.*—The control of mound colonies of the meat ant (*Iridomyrmex detectus Sm.*) is invariably followed by re-occupation of the treated site by ants from neighbouring colonies. A satisfactory insecticide for control of the meat ant must have a residual effect to prevent this re-occupation. Previous experiments have shown that a dust containing 2 per cent. chlordane was superior for the control of the meat ant to a 2 per cent. chlordane spray and to sprays and dusts containing 2 per cent. DDT.

During the summer of 1951-52 a series of colonies were treated with dusts containing 2 per cent. DDT, 2 per cent. chlordane, 2 per cent. dieldrin, and 2 per cent. aldrin at a standard rate of ½ oz. dust to each entrance hole. Two per cent. dieldrin dust killed out all colonies and prevented re-occupation after treatment; chlordane and aldrin did not give complete control, small numbers persisting in a few sites; DDT failed in nearly all colonies treated.

Incipient colony development by the meat ant has been studied over a two-year period. Six of the seven colonies remaining from the initial series plotted after an autumn nuptial flight on 20th March, 1950, were excavated at 540-611 days. These colonies each contained less than twenty workers plus 35 larvae and in some an entrance hole had not yet been opened up. The last colony was excavated at 668 days and contained a total of 113 workers, pupae, larvae, and eggs.

Incipient colonies from a spring nuptial flight on 15th October, 1951, developed more quickly and workers were present at 95 days. Many of the colony-founding females died during the very dry period January-March, 1952, and at 198 days the largest colony contained 22 workers and 49 larvae.

It was observed that the worker ants in incipient colonies retreat to their galleries when disturbed, whereas those in mature colonies are aggressive. This difference in habit, and the fact that it may be up to two years before an incipient colony develops sufficiently to open up an entrance hole, has resulted in incipient colonies occurring in large numbers after areas had been freed of the more obvious mature colonies by the application of insecticides. These results, together with the ability of a female meat ant to fly several hundred yards into a treated area during a nuptial flight, explain some of the failures in attempts to eradicate the meat ant.

11. CATERPILLARS OF PASTURES AND FIELD CROPS.

A survey has been commenced of the distribution, seasonal incidence, and relative economic importance of a series of caterpillar pests which destroy pasture and field crops in Australia. Species that are restricted to one or two special crops are not being considered, as most of these are kept under close observation by the State Authorities. Some 30 essentially polyphagous species are recorded as injurious and of these the cutworms and armyworms (Noctuidae) and the webworms (Pyralidae) constitute the greater number. Several cosmopolitan species occur in the Commonwealth, but native species are also frequently involved.

Of immediate importance is the accurate identification of larvae collected during outbreaks or on field surveys. No attempt has previously been made in this country to define the characters that distinguish the immature stages of the pest species. For this purpose, series of larvae and pupae are being reared in the laboratory from eggs laid by named adults collected in the field. Observations are being made simultaneously on certain aspects of larval behaviour and techniques are being developed for rearing the various species.

The adults of the cutworms and armyworms, as well as some Pyralidae, are strong fliers and many are known to be migratory. Adult migration is probably important in determining the seasonal incidence and distribution of outbreaks of pest caterpillars. In the spring and autumn, observations were made on migratory flights of a cutworm moth, *Agrotis infusia,* in the Australian Capital Territory. Known as the bogong moth, it occurs in vast numbers during the summer on mountain tops in south New South Wales and in Victoria, where it formerly constituted an important article of food for aboriginal tribes. Investigations on large assemblages of these moths, crowded in small caves and crevices in granite outcrops at altitudes of 4,000-6,000 feet, showed that they remain in these situations from early November until the end of March. During this period they neither fed nor copulated and the ovaries of the females remained undeveloped. Laboratory experiments with moths taken from these assemblages and reared from larvae showed that sugar food is necessary before normal mating and the production of fertile eggs are possible. Strong evidence has been obtained that *A. infusa* moths of the spring generation migrate in swarms to the mountains, where they aestivate gregariously during the summer. In autumn the same individuals again migrate, presumably to their breeding grounds. The larvae of this species have often been reported injuring crops in south-eastern Australia. Field surveys during the winter are expected to yield information about the areas in which the larvae normally occur and where outbreaks are able to develop in favorable circumstances. Comparative studies of the ecology of this and two other important cutworms, *Euxoa radians* and *Agrotis ypsilon*, have also been commenced.

12. INSECT PESTS OF STORED PRODUCTS.

With the aim of developing methods of grain storage that eliminate losses due to insect and rodent pests without the need of periodic fumigation or insecticidal treatment, plans for an experimental underground pit have been drawn up. No agreement has yet been reached on its construction. Although considerable field experience in the method has been gained overseas, there is little factual information on the events occurring in a hermetically sealed pit and experimental work has therefore been begun to determine the precise effects of carbon dioxide concentrations and oxygen deficiencies on grain pests. Concurrently the gaseous exchanges produced by the respiration of insects and grain under hermetic conditions are being investigated.

Initial work on the entomological problems of the flour milling industry has aimed at ensuring an insect-free product rather than at the control of insects within the mills themselves. In this connexion a commercially produced continuous-flow percussion machine has been shown to be fully effective in destroying any insect life present in flour. However, much of the value of such a treatment is lost if the foodstuff is subsequently stored in an infested warehouse or loaded into infested transport, as insects are able to penetrate all packaging materials normally used, with the exception of tin plate. Attempts have, therefore, been made to develop a satisfactory insect-proof material for the packaging of foodstuffs. The use of insecticides and repellents has certain disadvantages and attention has been given to physical barriers. Determination of the hardness of insect mouth-parts showed that they were capable of biting through the commoner metal foils and that much harder materials would be required to stop them. Such a material would have to be flexible to be of practical use and would therefore have to be in the form of finely divided particles supported by bonding to a flexible backing material. Common mineral dusts have been tested and are effective except where the coating cracks along crease lines. Sandpaper has been used overseas but has suffered from the same disadvantage. Promising methods of overcoming this and of providing an adequate seal at the mouth of a package are being investigated.

During the year a review of physical methods of sterilizing foodstuffs was undertaken. This covered the use of heat, high frequency electric fields, ultrasonics, and ultraviolet light. It was concluded that, except for the use of heat in certain limited applications, these methods do not at their present state of development offer economic insect control.

13. OTHER INVESTIGATIONS.

(*a*) *Susceptibility of Insects to Insecticides.*—(i) *Housefly.*—Investigations were continued on three strains of flies differing in susceptibility to DDT. The Queanbeyan strain, which was initially much more resistant than the laboratory strain, lost its resistance fairly rapidly when reared through several generations in the absence of DDT. At the fifteenth generation it was shown to be about 30 times as resistant as the laboratory strain, and there is some evidence that in earlier generations its resistance was still higher. By the twentieth generation it had decreased in resistance to less than twice that of the laboratory strain. A similar loss of resistance occurred in the Black Mountain strain, which was initially intermediate in resistance between the above strains. The rearing method used was not responsible for these losses of resistance, since the susceptibility of the laboratory strain did not change appreciably over a similar number of generations. Further work on the factors determining susceptibility has been planned, but cannot be undertaken until improved facilities for precise toxicological experiments become available in the new insecticide laboratory.

(ii) *Drosophila.*—During a visit by an officer of the Division to England, work was carried out at Rothamsted Experimental Station, Harpenden, on certain factors which influence the susceptibility of *Drosphila* to DDT. A special microburette was made for dispensing insecticide solutions accurately, in very small dosages of the order of 0.005 μl., and this was used in applying measured amounts of DDT to individual flies of various ages. Susceptibility to DDT was found to vary markedly with age, being relatively high in young flies, but decreasing to a minimum in flies five days old. After five days, males rapidly became more susceptible again, females only slightly so. Respiration rate was measured in untreated flies of various ages, and was found to be closely correlated with resistance to DDT, suggesting that resistance is determined by the ability of the flies to detoxify DDT metabolically.

(*b*) *Contact Insecticides.*—An extensive study of the performance and scope of apparatus designed to produce uniform experimental deposits of insecticide, and sprays of uniform droplet size, is nearing completion. Several modifications have been made to improve the reproductibility of deposition rate and to extend its droplet size range. It is expected that this instrument will facilitate and add to the precision of work with contact insecticides.

(*c*) *Lucerne Flea.*—A field experiment has been commenced this year on the control of the lucerne flea in pastures. Insecticides have been applied by means of a low-volume boom spray. BHC at the rate of 2 lb. 50 per cent. dispersible powder/acre gave no control at all. Chlordane at the rate of ½ lb./acre gave a 70 per cent. kill and "Phosfone" at the rate of ¼ pint 20 per cent. emulsion/acre gave a 97 per cent. kill. "Phosfone" has proved to be a highly efficient and quickly acting insecticide against this pest. Its persistent effects are not yet known but will be investigated during the season.

(*d*) *Wood Borers.*—The powder post beetle, *Lyctus brunneus*, has been reared successfully on an artificial diet of starch, sugar, casein, yeast, and cholesterol. This has made it possible to study the effect on larval development of various plant extractives (alkaloids, &c.) that are present in timber species, e.g., *Cryptocarya glaucescens* and *Melicope australasica*, which are immune to *Lyctus* attack, by adding such extractive materials to the basic diet.

(*e*) *Standard Common Names of Insects.*—The compilation of a list of standard common names of insects and related pests, which was initiated by the Division of Entomology, has been handed over to a representative committee of Australian entomologists. The Division has one representative on the committee of five. Considerable progress has been made.

(*f*) *Survey of Cocos Islands.*—In May and June, 1952, at the request of the Department of Civil Aviation, an officer of the Division was sent to the Cocos Islands to study the insect population there. The object of this investigation was to obtain information on the insects present there and to assess the danger of potential introductions into Australia when the new air route opened between South Africa and Australia. A comprehensive collection, some 2,000 specimens, was made on the islands and the officer also visited museums at Singapore and at Kula Lumpur, in Malaya, where parts of a previous collection from the Cocos Islands were housed. The information obtained in this survey should assist in formulating measures for disinsectization of aircraft as well as being of direct assistance for quarantine purposes.

14. Taxonomy.

As in previous years, specialists both within the Division and elsewhere have continued taxonomic work on various groups of insects. This work is mainly confined to the groups which are of particular importance in economic entomology. The first part of a monograph on Australian ants has been published. Work is being continued by a United States authority on the revision of the Australian locusts and grasshoppers. The Division's collection in the two parasitic wasp families, Ichneumonidae and Braconidae, is being studied by a New Zealand authority who is engaged in a revision of these groups. Detailed revision of certain groups of the Australian Diptera (flies) has been continued during the year and it is expected that other groups will be included in this revision in the near future. Particular attention is being paid to the parasitic wasps, of which the most important is the Chalcidoid group, one of the largest and most difficult to classify of all Australian groups of insects. It will probably be many years before this group has been satisfactorily classified and revised. Other families of insects which are being studied by different officers of the Division are the Australian Tortricidae, a moth family containing several pests, various groups of the Hemiptera; cockroaches; and grasshoppers.

X. WILD LIFE.

1. General.

The Wildlife Survey Section studies economically important mammals and birds. Because of the great economic losses the rabbit causes, the problem of controlling it has absorbed most of the Section's efforts.

2. Rabbit Investigations.

(*a*) *Myxomatosis.*—Work on the virus disease, myxomatosis, has again dominated the activities of the Wild life Survey Section. The widespread epidemic which got under way in the summer of 1950-51 developed in an interesting and somewhat surprising manner during the winter of 1951 and the following spring and summer. An attempt has been made to follow the general and local developments of the epidemic; in addition, special studies of the insect vectors responsible for the transmission of the disease in the field have been undertaken.

During the winter the infection was found to persist, generally at low intensity, over an extraordinarily wide area. Much of the winter smouldering was of a diffuse nature and associated with patches of saffron thistle (*Carthamus lanatus*), but other outbreaks were localized around small swamps, hillside seepages, &c. It is suspected that the vectors responsible for winter transmission were ectoparasites. The winter observations are important in that they indicated that the infection could persist in the wild rabbit population, and that myxomatosis could be expected to become endemic in Australia.

State-sponsored campaigns of virus dissemination and inoculation were begun early in the spring of 1951, and they were followed in the summer by disease activity on a huge scale, much of it in a belt of country in which myxomatosis had failed to make headway during the previous season. By the autumn of 1952, the main epidemic area had been extended to include: (i) the south-eastern district of South Australia, between the Murray River and the coast, (ii) the greater part of the State of Victoria, (iii) the Murray, Murrumbidgee, and Lachlan valleys, and (iv) the foothills and undulating grazing country between the eastern highlands and the plains of New South Wales, and substantial sections of plains country. In addition there was a good deal of scattered disease activity in the highlands themselves, and on the coastal belt. Prolonged drought curtailed myxomatosis activity north of the Queensland border, but did not prevent it entirely.

The intensity of myxomatosis activity over this huge area was subject to considerable variation; and it is difficult to assess the overall effect of the epidemic. Useful " controlling " kills were recorded over considerable areas, and a substantial reduction in rabbit population density was achieved over the whole epidemic region. The response of pastures to the lightening of rabbit grazing has been most satisfactory.

The vector investigations of the field station at Albury were confined, in the main, to the eastern Riverina, where mosquitoes are the dominant vectors. The sequence of seasonal abundance of the more important species has been worked out, and useful data have been obtained on the range and habits of some suspected vectors. By correlating the performance of myxomatosis in space and time with changes in the mosquito fauna, backed up with some observations on the behaviour of the different species, it has been determined that *Aedes theobaldi* and *A. sagax,* the common day-biting pest mosquitoes of the inland, are inefficient vectors, and that *Anopheles annulipes* is a vector of major importance. The vector role of the last-mentioned species was experimentally confirmed. It was found to be present (either as adults resting in daytime in the warrens, or breeding) in almost every outbreak area surveyed during the height of the 1951-52 summer epidemic. It is believed to have been the vector primarily concerned with the spread of myxomatosis away from the rivers to the neighbourhood of which the infection was largely confined during the first phase of the epidemic.

In addition to the field studies, laboratory investigations on the transmission of myxomatosis by rabbit ectoparasites have been undertaken and it has been shown that the louse *Haemodipsus ventricosus* and two species of mite, *Cheletiella parasitivorax* and *Bdellonyssus bacoti,* could act as vectors. It is now suspected that most of the presumed transmission by contact is expicable on the basis of ectoparasites acting as vectors.

The problem of immunity has come to the fore in the past season, with the observation that recovered animals were to be found in some numbers in the field. Blood samples and field data have been supplied to Professor F. Fenner, of the Australian National University, for his current investigation of this problem. The degree to which immunity is heritable has not yet been determined, and thus the danger of the rabbit population developing a degree of resistance to the infection cannot yet be assessed.

In the last Annual Report mention was made of the fumigating machine designed to blow a chloropicrin-oil aerosol into warrens. In anticipation of the possible need to infect large numbers quickly, in order to take advantage of special local conditions that called for study, this equipment was modified so that it could be used to atomize and introduce into warren colonies a suspension of myxomatosis virus. Field trials indicated that this was a very effective method of establishing the disease, but in view of the difficulty of preparing a suitable virus suspension the technique can be regarded as no more than a research tool.

A summarized account of the history of the current myxamotisis epidemic and of the vector investigations has been prepared for publication in *Nature*.

(*b*) *Other Rabbit Investigations*.—The basic ecological studies and the work on fumigation and on poisons were very severely curtailed during the year because of the demands of the myxomatosis investigations. Some useful data have been obtained, however, on reproduction and feeding and other behaviour of rabbits and on internal parasites. A survey of the seasonal and regional prevalence of the helminth parasites of the rabbit has been initiated. Of the three nematodes, *Trichostrongylus retortaeformis* was found in all regional samples and specimens examined, *Passalurus ambiguus* in most, but *Graphidium strigosum* was not found in northern New South Wales (Moree and Armidale districts).

3. Mutton Bird Investigations.

The investigations carried out in collaboration with the Tasmanian Fauna Board on the economic biology of the mutton bird (*Puffinus tenuirostris*) were continued in the Furneaux Island region.

The Tasmanian mutton bird is a migratory species, and individuals arrive at the nesting islands from about the third week in September. The period of egg-laying is remarkably constant, being from about 20th November to 30th November, and the young are ready for commercial harvesting by the third week in the following March. By the beginning of May all the birds, adults and surviving progeny, migrate, the bulk of the population moving for the winter months to the north Pacific. The commercial activities are limited to taking the fledglings, which are used for food. The catch is mostly salted, but during the 1952 season some fresh birds were frozen and air-freighted to Tasmania. The canning of young birds ceased with the closing of the fish-canning factory at Lady Barron, Flinders Island, in 1949. The stomach oil, body fat, and down feathers are also marketed.

During the investigations on Fisher Island on general life history of the species, 325 adult birds were handled in 1951-52, compared with 290 in the previous season. It was estimated that 140 breeding pairs occupied the island, compared with 145 in 1950-51: this slight reduction may be due to the inroads of water rats (*Hydromys chrysogaster*), which killed many of the fledglings. It was possible to record and identify 95 per cent. of the breeding adults, compared with 90 per cent. the previous season; and about 21 per cent. of them were birds that were ringed in 1947, and had thus returned to the island for the fifth successive season. This is a minimum figure, as an unknown number of birds had lost their original copper rings before being re-ringed with the monel metal bands now in use. Again, no bird of known age (i.e. that had been ringed as a fledgling during the currency of this study) was recorded at Fisher Island as a breeder.

The monel metal rings have now been under practical test since March, 1950, and they are proving very satisfactory. They appear to provide the answer to the problem of marking such birds as the burrowing petrels, where physical abrasion combined with the corrosive action of sea-water renders the standard aluminium rings unserviceable.

Before the opening of the commercial birding season on 23rd March, the field party ringed 1,648 young birds on the islands that would be harvested. The object is to measure the intensity of hunting and the degree of escapement of the young.

An experiment in the rehabilitation of mutton-bird rookeries whose carrying capacity has been impared, mostly by grazing and the trampling of stock, was carried out on Little Green Island. On "hard ground" and in a sparsely occupied rookery, a series of artificial burrows was drilled with a post-hole borer before the birds arrived in the spring. In four test plots the percentages of such artificial holes occupied by breeding birds were 83, 44, 66, and 80, with an overall percentage of 66. These results have encouraged further experimentation.

Observations on the mortality among mutton birds that occurs along the eastern coast of Australia during the spring migration were continued as usual in 1951. For the ninth year in succession a low mortality was revealed.

4. Kangaroo Investigations.

Some preliminary observations and experiments in control have been made in connexion with the kangaroo problem in Western Australia, where three species of kangaroo are serious competitors of sheep for grazing and water.

In the north-west, the troublesome species are the red or plains kangaroo (*Macropus rufus*) and the euro (*M. robustus*). The former is a nomadic inhabitant of grass plains and is the species sought by hunters for skins. Some pastoralists are satisfied that the red kangaroo could be kept in satisfactory control by hunting combined with poisoning at water troughs (arsenicals are commonly used). The euro is a more sedentary species, inhabiting particularly the rough hill country in the spinifex belt; in recent years it has developed into a serious pest on sheep stations in the Roebourne Tablelands and the vicinity of the Barlee Range. It presents a more difficult control problem since it is avoided by hunters because of the low value of its skins, and the nature of its habitat sets a limit to the efficacy of water poisoning. In the West Kimberley the pest species is the jungle kangaroo or sand wallaby (*Macropus agilis*).

One possible method of dealing with these marsupials was suggested by the natural lack of salt in the region, and the kangaroos' habit of frequenting the salt licks put out for sheep.. In a preliminary trial, sodium fluoroacetate ("1080") was selected for incorporation with salt in licks, as it is a poison that combines high toxicity with acceptability. The results obtained, both with the plains kangaroo and with the euro, were disappointing, but the efficacy of the poison when added to drinking water at the rate of about 0.05 oz. per gallon was demonstrated in a subsequent trial. The investigations are being continued.

XI. FISHERIES.

1. General.

Investigations of Australia's marine resources are made by the Division of Fisheries, which has its headquarters at Cronulla, New South Wales. Work on the preservation of fish is carried out by the Division of Food Preservation and Transport and is described in Chapter XII., Section 6.

Pending the commissioning of the trawler-oceanographic vessel at present under design there has been some decrease in the deep-sea research of the Division. During the year, the sea work was maintained by the Division's F.R.V. *Derwent Hunter* and pearling lugger F.R.V. *Gahleru*, by charter of suitable vessels, and by visits of scientific officers to sea on board commercial fishing vessels.

Whaling investigations were intensified in view of the development of the Australian whaling industry. A study was begun of the availability of fish in the deeper waters down to the edge of the continental shelf.

Ecological investigations (as a preliminary to an intensive study of these areas for fish culture) were commenced on an enclosed brackish to fresh lake on Moreton Island in Queensland and on a partly enclosed area in Port Hacking used in the early years of the century as a fish-culture pool for fish introduced from overseas.

Investigations on fouling of vessels and sea structures and the survey of the availability of the brown seaweed *Macrocystis pyrifera* were tapered off and results were prepared for publication.

The co-operation of the Australian Whaling Commission and of Whale Industries Pty. Ltd. in providing facilities and accommodation at Babbage Island, Carnarvon, Western Australia, and at Moreton Island, Queensland, for the Division's scientific officers has made possible detailed biological observations on whales in western and eastern Australia.

Onshore hydrological traverses and prawn and crayfish surveys in the Garden Island and Hamelin Bay areas of Western Australia were carried out with the small craft of the Department of Fisheries and Game, and this assistance is acknowledged.

2. Operations of Research Vessels.

(*a*) *F.R.V.* Warreen *and F.R.V.* Stanley Fowler.—The original research vessel of the Division, F.R.V. *Warreen,* underwent a main engine refit and was transferred to the Royal Australian Navy in December, 1951. On 31st August, 1951, F.R.V. *Stanley Fowler* was returned to the Navy on the expiry of a three year's loan.

(*b*) *F.R.V.* Derwent Hunter.—This vessel was designed and built as a crayfish boat and required extensive alterations to fit her for general research purposes.

(*c*) *F.R.V.* Gahleru.—The alterations to this vessel were completed and she sailed to Thursday Island in September, 1951. She is a 45-ft. auxiliary ketch-rigged wooden vessel built as a yacht. She has been adapted to work as a pearl-shell diving craft attached to the Thursday Island Research Station.

She has made five cruises during the year, mainly for building up stocks of live *Pinctada maxima* (pearl shell of commerce) for biological studies and pearl culture. A request was received from the commercial pearlers of the area for a survey of an extensive area west of Thursday Island to locate new shell patches. Before the last war this area had reputedly yielded good shell from reasonable depths, but at present it is unworked. Twenty-three working days were spent in the area, and close surveys were made of seven small areas where shell has been reported either in Japanese manuscript or by local divers. No payable shell beds were located and very little shell was seen. It was thus concluded that either the locations given were inaccurate or the previously existing shell beds had disappeared. In June a survey of the pearl-shell beds at Groote Eylandt was commenced.

During September-November, 1951, the Division chartered fishing vessels in north Queensland, the *Barrier Princess* from Innisfail and the *Kywong* from Townsville, so that biological information on Spanish mackerel could be obtained.

3. Whaling.

Following the appointment of an officer for whaling research, a full programme of investigations was entered upon at the commencement of the 1951 season.

The humpback, the only whale of economic importance in Australian waters, has not been subject to the considerable scientific investigations lavished upon the blue and fin whales: research, therefore, was planned to be wide and fundamental so as to form a sound basis for comparison with other and subsequent work. Detailed biometric and other observations have been obtained from 500 whales. Particular attention has been paid to the examination of gonads and of the ossification of the vertebral column in order to determine the onset of sexual and physical maturities.

The material examined shows that the female humpback whale frequenting the Western Australian coas attains sexual maturity at a total length of 39-40 feet a figure less than that arrived at by earlier but rather inadequate *Discovery* work. Based on testis weight verified by histological examination, sexual maturity was demonstrated to be reached in the male at a rather shorter length than in the female. The number of mature males in the catch was found to increase notably as the season wore on. Another significant change discovered during the season at Carnarvon was the marked and steady decline of the proportion of females in the catch from an initial high percentage. This variation in the proportion of the two sexes was found to be less marked, although apparent, in the catches of the Poin Cloates station and it may be due to differences in the local populations off the two stations.

State of physical maturity is determined from an examination of the degree of ossification of the vertebral epiphyses. During the course of the season 451 humpbacks were thus examined and the surprising result obtained that extremely few of these whales had reached full physical maturity (only 0.28 per cent. of the males and 2.33 per cent. of the females). By far the greater number showed no signs of approaching physical maturity, only displaying the early stages of epiphysial fusion. There exists no published record of a similar kind with which to compare these figures but it is obvious that close attention must be paid to this outstanding phenomenon, which indicates that although physical maturity may be attained relatively late in life, the stock upon which the Carnarvon whaling activities are based is composed of relatively young whales.

Pituitary glands have been collected, annotated, and preserved for analysis by the Department of Biochemistry of the Australian National University.

An interesting event occurring towards the end of th season was the recovery of one of the Division's own whale marks fired into a humpback whale from F.R.V *Warreen* two years earlier. The positions of marking and of capture were only a few miles apart, indicating the remarkable adherence of this whale to its migrating paths. A second mark fired by the R.R.S. *William Scoresby* fifteen years earlier in Antarctic waters wa also recovered. Unfortunately, neither of these two whales could be examined by our research officer. Much of the value to be derived from marking is lost in such cases.

A progress report of the work done and the conclusions reached was, in accordance with the obligation of Australia as a full member, prepared and submitted to the International Whaling Commission in time fo its fourth meeting in 1952.

With the opening in June, 1952, of whaling operations from Moreton Island, on the east coast, a second scientific officer was detailed to make the necessary biological observations.

4. Sea Fisheries.

(*a*) *Echo-sounder Data.*—Interesting data on echo-sounding were collected on F.R.V. *Warreen* during May and June, 1951. In the interpretation of thes data the echometer has been considered as a biologica tool and the records used to calculate the size o pilchard shoals and, in connexion with net catches, th density of fish in the shoals. The total quantity o shoal fish thus indicated has been estimated for tw parts of the coast. Movements and dispersion of shoal and their feeding have also been studied. These dat have been prepared for publication.

(*b*) *Barracouta.*—Since the F.R.V. *Derwent Hunter* was available only for one month of the year, the investigation of barracouta was restricted to the working up of previously collected data, and observations on the landed catch (headed and cleaned).

There was a scarcity of barracouta in Bass Strait in the 1950-51 and 1951-52 seasons. The situation recalls that of 1940 and 1941, when the Division's efforts to encourage the canning of barracouta were frustrated by a shortage of fish, although later in the war these efforts were successful. In the intervening decade the fish were generally plentiful, towards the end of that period the supply was much in excess of demand. This position has now been reversed.

It is not possible to obtain a clear picture of such fluctuations until the approximate geographical limits of the different stocks or populations of the species have been determined. Normally there are such different stocks within a species, some of which may, over a given period of time, fluctuate in abundance (but not necessarily all in the same way) and some not. The identification and delimitation of these stocks are of fundamental importance. Evidence so far available suggests that there are three main stocks in the area of the barracouta fishery, one in Bass Strait (spawning in spring and summer), one on the east coast of Tasmania (spawning in summer and autumn), and one in eastern Victoria and southern New South Wales (spawning in winter and spring). There appears to be a different stock in eastern South Australia (spawning in autumn and winter) which, although unfished there, occasionally penetrates into western Victoria and contributes to the catch of that region. The Bass Strait stock appears to make a westward spawning migration through the Strait in the spring and early summer, and an eastward return movement in the late summer and autumn. This hypothesis requires further proof. It was hoped to prove or disprove the hypothesis of a homogeneous stock in Bass Strait by mass measuring of the commercial catch on both sides of the Strait in the 1951-52 season, but the scarcity of fish made it difficult to carry out this programme in its entirety.

Studies of age-determination of barracouta, using otoliths, were commenced. The otoliths are not easy to read, although they are more legible than the scales. The age of fish in the commercial catch appears to range from about five to ten years.

The seasonal cycle of bodily condition is being further studied. As was expected, there is a tendency for fish caught in the middle of the fishing season to be leaner than those caught earlier and later, but the amplitude of this fluctuation seems to vary greatly from year to year. Percentage oil contents are being determined separately for head, viscera, and fillets of barracouta. The results so far indicate that reduction of the viscera and heads to oil and meal might be economically feasible under certain conditions; at present these portions of the fish are thrown away at sea. However, more work is required before a definite statement can be made.

(*c*) *School Shark.*—A paper on the biology of this species of shark is almost complete.

The recent capture of several adult tagged sharks and the return of the carcasses for accurate measurement have made possible a check on the accuracy of the growth-rate curve derived by other means. It was found that there was excellent correlation between the theoretical and actual values for length increases of tagged sharks. These results have given added weight to the deductions made about the age at sexual maturity.

It has been proved that there is only one stock of school sharks in south-eastern Australian waters.

(*d*) *Tuna.*—Completion of a year's observation on distribution of striped tuna on the east coast showed seasonal movement. They occur on the New South Wales coast during winter, spring, and early summer, and are abundant off Tasmania in late summer and autumn. There is a significant correlation between distribution and specific water temperatures; thus striped tuna occur most plentifully in the range 16°–18° C., and the overall temperature range within which the species is taken is from 14.7° to 21° C.

Observations in Tasmanian waters showed significantly smaller occurrences of striped tuna in 1952 than in 1951, which may be due to a remarkably strong invasion of salp into waters of the continental shelf in 1952.

Examination of the stomach contents of striped tuna caught on the mid-New South Wales coast disclosed that the food was exclusively larval fish; hence striped tuna may be expected to be caught more easily by the live-bait method than by trolling. This probability was demonstrated by the Division in 1940, and the past year has seen the beginning of commercial live-bait fishing for striped tuna on the New South Wales coast from Eden.

Measurements were recorded of bluefin tuna taken in Tasmania and New South Wales. Specimens of the 3-4 lb. size-group were taken off Shoalhaven Bight in New South Wales. In Tasmania the weight ranged from 25 to 50 lb. but some larger specimens up to 140 lb. were taken.

The data collected between 1939 and 1950 on the species of tuna taken in Australian waters have been analysed and are being prepared for publication in a series of papers, two of which are now almost completed.

(*e*) *Pilchards.*—The commercial fishing boat *Jon Jim*, which caught 40 tons of pilchards by purse seining in King George's Sound, Western Australia, in the 1951 pilchard season, caught over 50 tons at the same season in 1952, in spite of a late start. All technical fishing difficulties have been solved.

Records of surface shoals of pilchards in the southern waters of Western Australia, accumulated by F.R.V. *Warreen* from 1947 to 1951, were compiled and analysed in the same way as was previously done for pilchard shoals in New South Wales waters. For the coast as a whole the quantitative index of availability of shoals from March to June was about the same as that for New South Wales at the same season. However, in King George's Sound alone the index for the season was particularly high, shoals being seen on more than half the total number of days employed in looking for them.

The pilchards caught in King George's Sound in 1951 were mainly four-, five-, and six-year-olds. This is in line with scantier observations from the same locality and other Western Australian localities in other years. It is curious because in New South Wales, where conditions for pilchards appear to be comparable in most other respects with those in Western Australia, the two-year-olds generally predominate and specimens over four years old are not often taken. A few pilchards of seven years of age have now been observed in Western Australia.

(*f*) *Australian Salmon* (Arripis trutta).—The investigations have been concentrated mainly on the racial relationships of the salmon from Western Australia, South Australia, and Tasmania. A detailed morphological comparison does not yield any population difference between stocks of the three localities.

Recent sampling of some of the large schools in South Australian waters has revealed large salmon of from 7 to 9½ lb. These fish, from their size, must have spawned previously. It is thus necessary to depart from the hypothesis previous advanced that large salmon occur only in Western Australia.

At the time these large fish were taken in South Australia the large salmon in Western Australia were moving along the coast in a spawning migration, but those in South Australia showed all the characteristics of a non-spawning group of fish. It is thus probable that the South Australian large salmon have a different reproductive cycle from the Western Australian fish and thus constitute a different population.

Field work done in South Australia in June, 1952, concentrated on the problem of the movement of small salmon. Large quantities of small salmon were tagged to determine whether they move into Western Australian waters.

During late April several hundred salmon were tagged and released from the salmon pens at Lakes Entrance. Some recoveries were obtained from the Lakes Entrance area and two from Eden, New South Wales.

(*g*) *Ruff* (Arripis georgianus).—The determination of spawning migration and definition of populations are being studied by tagging.

(*h*) *Australian Trawl Fisheries.*—An officer has recently been appointed to continue the work done on this fishery by the late W. S. Fairbridge. He is at present examining the data that have been collected during the last two years, and has commenced an inquiry into the potentialities of a trawl fishery in the Great Australian Bight.

(*i*) *Horse Mackerel.*—Investigation of this species is dependent on supplies of fish taken by commercial fishermen. Since 1948 fishermen have taken increasing interest in tuna fishing and the catch of horse mackerel has not increased, although purse-seine methods of catching large quantities have been demonstrated. Indications are that, under present economic conditions, a fishery for horse mackerel is unlikely to develop on either the New South Wales or Tasmanian coasts.

5. Estuarine Fish.

(*a*) *Mullet.*—During the year, 995 sea mullet were tagged and 25 tags were returned (2.5 per cent. return). Sampling along the Logan River-Amity Point line, Queensland, indicates that the small mullet fry enter Moreton Bay during late August to early October and work their way more or less rapidly up into the rivers, being plentiful in the freshwater zone by mid-December, though the greater number appear to concentrate in the upper portion of the tidal estuary. The older (III+ and older) fish appeared only spasmodically in the upper river, and never in numbers.

Tagging has indicated that during early or mid-summer the mullet schools remain within a circumscribed area in the bay or estuary; towards the end of summer the schools of II+ fish tend to break up and travel in small groups about the bay or even up into the freshwater zone of the rivers. At the same time the larger fish are accumulating into schools prior to the sea mullet run.

In Western Australia, 415 mullet were tagged between June and December last. Results for the period January to June, 1952, are not yet to hand. Five tags were returned from June to December, 1951.

(*b*) *Fish Culture.*—Fish farming has been developed in Europe, China, Japan, India, the Philippines, and Indonesia. The Division is now preparing to make a careful survey in two areas which should yield valuable information for the guidance of future large-scale experiments in estuarine fish farming in Australia. One experiment is being made (opposite the Cronulla Laboratory) at Maianbar in Port Hacking, New South Wales, and one at Moreton Island Lagoon (near the Dunwich Research Station) in Queensland. A similar, though rather specialized experiment, is being carried out in Lake Dobson, a freshwater highland lake in Tasmania.

The dyke at Maianbar has been partly constructed. The gates will not be placed in position until an ecological and hydrological survey of the area in its unenclosed state has been completed.

It became evident that the survey of these areas would involve a team of scientific workers, including a hydrologist, a biochemist, a microbiologist, a zoologist, and a fisheries biologist. The report on hydrological investigations is included in Section 9 of this Chapter. The microbiologist's report is included in Section 11 (*a*).

Nets are now being made so that the present population of the area may be estimated, and a fish trap has been planned which will give an estimate of fish entering and leaving the area.

The zoologist reports that collections have been made from fifteen representative stations. Fauna from the shore stations have been collected by formalin weed washings and sand washing. A modification of the Holme scoop sampler has been used for taking samples off the bottom. There are apparently no living metazoon populations in the bottom mud at present; but the *Zostera*, *Ulva*, and other weeds support a fair crustacean and molluscan population.

Growth rates and population densities of *Branchidontes* and *Pyrazus* are being determined.

In December, 1951, after commercial fishermen had pronounced the lagoon at Moreton Island, Queensland, as being fished out and after repeated settings of nets (by this Division) had failed to yield more than a few fish per overnight set, a large number of fish were killed as the result of deoxygenation following a fantastic bloom of *Nostoc* sp. It was estimated by local fishermen that more than 50 cases of fish were lying around the edges of the lagoon, mainly mullet and whiting and a few very large bream. All the fish were not killed, as mullet were observed jumping on later occasions. At this stage very few small fish had been introduced. It is intended to watch the pH carefully and to treat the water with sodium arsenite whenever the algal bloom becomes dense. According to local residents a similar occurrence took place five years ago.

The plankton, which had consisted almost entirely of three species of copepods and small flagellates for about a year, was nearly non-existent immediately after the December catastrophe, the hauls being full of *Nostoc* filaments. After a few weeks the plankton settled down, with the flagellates present once more, but only one of the species of copepods has so far reappeared. This species is *Sulcanus conflictus*, which has previously been recorded from George's River and the Hawkesbury River in New South Wales and from the Swan River in Western Australia.

6. Freshwater Fisheries.

(*a*) *Trout Investigations (Tasmania).*—In response to a request from Tasmanian authorities a study has been commenced on the alleged deterioration in trout fishery in the rivers and lakes.

Investigations have included tagging and scale examination. In some cases tagged fish when recovered after two years have shown no length increment and some loss in weight. Scale formation was often abnormal, indicating an age several years less than that indicated by the tags.

The cause of growth cessation has not yet been determined and the whole investigation is still in the stage of preliminary hypotheses.

(*b*) *Freshwater Fish Culture* (*Tasmania*).—The nvestigations in Tasmania have been concerned with Lake Dobson, a highland freshwater lake, and with eservoirs and dams so that the results may eventually e of use to the farmer.

This lake was originally chosen because of its very ow natural productivity. It was thought that if a ody of water normally so unproductive of fish could e made productive, significant effects might be xpected with lakes of high natural productivity.

The lake was first fertilized in 1949 with paper-bag parcels of P–N–K fertilizer, containing some crushed imestone, dropped from a boat as it described several raverses of the lake. These bags readily penetrated he soft organic mud of the lake. Organic fertilizers were avoided, principally because of large amounts of organic material already present in the bottom mud. In 1950-51 the same total fertilizer as in 1949 was broadcast over the northernmost half of the lake in a eries of monthly applications during the summer.

The effects of these applications of fertilizer have only become apparent and striking this year when, as a result of the 1949 distribution of parcels of fertilizer, very large and flourishing growths of the flowering aquatic plant *Myriophylum elatinoides* have appeared just where the bags penetrated the mud, so that a photograph taken from a high vantage point shows the exact pattern of the original traverses of the lake made by the boat from which the bags of fertilizer were dropped.

The plants bear a considerable fauna of stonefly larvae, caddis fly larvae, gastropod molluscs, amphipods, and other animals of more variable occurrence, which have been sampled quantitatively and regularly over the past nine months. Tests indicate that the plankton density of the lake is greatest near the plants, some forms possibly preferring the shady conditions.

The principal effects following the second fertilization (i.e. the series of 1950-51) have been on the plankton and, apparently, once again on the plants. The zooplankton has increased tremendously over the level obtaining before this second fertilization. Figures for the zooplankton population go back to April, 1948, and show how consistently low was the level until the last twelve to eighteen months. It is to be noted that the first fertilization (1949) did not produce any noticeable improvement in the plankton level, and this would have been expected, since here the fertilizer all went into the mud, while in 1950-51 there was opportunity for a good deal to get into solution. The zooplankton population has shown no tendency to diminish again and, indeed, the highest count yet recorded was obtained in May, 1952. The zooplankton increase has been accompanied by a steady decrease in the phytoplankton, at least as exemplified by the diatom population over the past eighteen months. This is presumably the result of increasing grazing on phytoplankton by the zooplankton. The second fertilization has also apparently increased the area of the bottom colonized by plants. As well as growing in clumps in the traverses already described, smaller clumps of *M. elatinoides,* which neverthtless seem to be increasing, have appeared around and between the main lines in the northernmost half of the lake. The fact that these clumps are smaller than those attributable to the 1949 fertilization, but that there are many more of them, and that they are restricted to the northern half of the lake, but randomly distributed, all foster the hypothesis that they are the direct outcome of the 1950-51 fertilizations, when the nutrients did reach the bottom, but not in so rich and localized concentrations as in 1949.

The bottom fauna of the lake is still low and shows no signs of increasing, though, as prefertilization figures are not available, it is impossible to say with certainty whether it is now higher than it was in its natural state.

As it was thought that Lake Dobson had reached a sufficiently high level of productivity, approximately 500 weighed, measured and tagged yearling trout were introduced into the lake in May, 1952.

Work has begun on an artificial lake at Deloraine in northern Tasmania. This is about 8 acres in extent, and was recently constructed for irrigation and as a water supply for stock. The owner was advised by officers of the Division to transfer aquatic plants from an old irrigation channel to the lake, so that, when the grassy growth on the bottom has been finally destroyed by submersion, water plants will be established. The plankton of the lake is low, the bottom fauna is lowest where the bottom soil is bare, more plentiful where the submerged grass occurs, and most plentiful where the aquatic plants (*Myriophylum variifolium*) have become established.

7. CRUSTACEA AND SHELLFISH INVESTIGATIONS.

(*a*) *Crustacea.*—(i) *Western Australian Crayfish* (Panulirus longipes).—This species is important because it provides an important portion of the craytails exported to the United States of America. The total catch in Western Australia was 7,000,000 lb., a slight increase on the catch for 1950. The analysis of the catch reveals that the fishery has extended into deeper waters and that the catch from shallower waters has declined both in quantity and in the size of individual crayfish.

The catch in the Abrolhos area for 1951 shows a decline in total catch (1950, 2,100,111 lb.; 1951, 1,650,000 lb.), in catch per man (1950, 18,800 lb.; 1951, 17,500 lb.), and in crayfish size (1950, 38 per cent. with carapace 2¾ inches long; 1951, 48 per cent. with carapace 2¾ inches long). The fishermen have again crowded into the area in the 1952 season, and a further decline is to be expected. Because of this decline, survey work has been continued in the Bunbury-Cape Naturaliste area, and individuals of the species have been observed on the reefs of that portion of the coastal shelf.

(ii) *Prawns.*—Surveys were conducted in the Warnbro Sound, Western Australia, area using the State Fisheries Department's vessel *Lancelin* in January. Small numbers of prawns (*Penaeus* sp., cf. *P. latisulcatus*) with ripe gonads were present to a depth of 10 fathoms. A bottom sediment study of Warnbro Sound was made in conjunction with this survey and the report is being prepared for publication.

(*b*) *Oysters.*—A handbook for oystermen has been prepared to provide guidance in the techniques of oyster farming. Assistance has been provided throughout the year to any oysterman requesting it. Three oystermen in the Moreton Bay area are now established on what may be regarded as orthodox oyster-farming methods. A number of others are trying out small areas of trays and sticks.

Growth studies have continued in the Moreton Bay area. It has been established that oyster spat from Southport, moved to Dunwich and Bribie Passage, do not grow as well as the locally caught oysters. This may be due to an inherent "physiological race" difference or to some environmentally-induced factor, or simply the effects of transportation. The last seems scarcely likely to cause an effect so prolonged as to continue over two years.

Spawning in the Amity banks-Moreton banks area has been shown to occur throughout the year, the major spawning times being in December and May. In December the amazingly high catch of 20,000 spat on one square foot was recorded on the station's experimental lease at Dunwich.

There has been no recurrence of the disease which affected the mainland oyster beds in southern Moreton Bay during the summer of 1951. Conseqently no further work has been possible on this problem.

Observations on the occurrence, growth, and reproduction of various oyster drills have continued throughout the year. The mulberry whelk (*Morula alba*) seems to be present on the Dunwich oyster beds in approximately the same density throughout the year. The numbers of the tingle whelk (*Bedeva hanleyi*), hairy whelk (*Monoplex australasiae*), rippled triton (*Cymatium aquatile*), and pseudo-almond purple (*Cronia pseudo-amygdale*) vary seasonally. The egg masses of the hairy whelk and the rippled triton have been definitely identified.

The experiment to establish the Pacific oyster (*Ostrea gigas*) was continued in Tasmania when, to test the feasibility of successful transport by air, a trial shipment of five cases of seed oysters was air-freighted from Japan to Pittwater, with negligible loss. They have become satisfactorily established. A survey of the acclimatization and growth of the Pacific oyster in Australian waters was published during the year. It was concluded that importation with a high rate of survival was possible if the time of transit from Japan to Australia could be kept to less than two weeks. Some spatting had occurred, but it was quite insufficient to replace the parent stock.

Graphs of water temperatures at Pittwater for 1949-50 show that the optimum temperature for spatting established by Dr. Imai of Japan, 23°-25° C., is not obtained in the area. As Port Sorell, on the north coast of Tasmania, contains hard bottom shell beds and has water temperatures significantly higher than those at Pittwater, three trays of Japanese oysters were transferred in May to determine whether this area could be developed as a spawning ground for this oyster.

Consideration is being given to flying in from Japan some 2,000,000 spat, with the object of establishing a breeding stock in Tasmania.

(*c*) *Scallops.*—With the exception of some beds in the Norfolk Bay, Tasmania, area, all the scallop catch has been taken from the D'Entrecasteaux Channel beds. These beds are showing every sign of intensive fishing and no new beds of any size have been located to support the fishery.

Both total yields and average weights are showing a marked decline. Average yield of meat for the first month of the 1952 season was approximately 24 lb./1,000 scallops compared with 28 lb./1,000 for the first month of the 1951 season.

As a result of the biological research work carried out on scallops and a study of the water temperatures of the Channel, it has been possible to predict the biological condition of the scallop fairly accurately two months before the opening day of the season. This prediction was made and tested this year, and results have confirmed the accuracy of the forecast.

The experiment of restocking a depopulated bed with juvenile scallops proved a failure. During the time of the transfer of the 80,000 young scallops extremely inclement weather conditions were experienced which must have been inimical to survival. Temperatures as low as 37° F. (3° C.) were experienced. There were strong winds and consistent rain throughout the work.

Diving investigations on the scallop beds to study their ecology have determined that the minimum concentration of scallops at which the industry can operate economically is two scallops to the square yard. One of the main provisions of this low concentration is that the meat yield of scallops must be not less than 32 lb./1,000.

The starfish predation on the scallops is an important factor in the welfare of this fishery. In two years the population of juveniles on one bed has been reduced approximately 60 per cent. by starfish (*Coscinasterinas* sp.)

As predicted earlier, beds of young scallops spawned in 1948 have not entered the fishery this year. It was expected that they would reach the minimum legal size in five years, and there is every indication that most of the undersized scallops spawned in 1948 will enter the fishery next year. In an occasional area where the concentration has been high some stunting in growth is occurring, and as a consequence these fish may be undersized during the 1953 season.

8. PEARL SHELL.

Since the F.R.V. *Gahleru* has been based on Thursday Island the field work of the station has been greatly increased.

Field measurements and observations on the size, proportional measurements, grading of shell, pearl yield, sex, and gonad development of *Pinctada maxima* are being made regularly on the *Gahleru.*

A new site for spat setting and other observations has been occupied. This is an enclosed area of water close to the mainland coast and surrounded by islands. It is known that *P. maxima* exists in natural conditions on the bottom in the immediate vicinity. A raft has been constructed and moored, and spat setting plates, &c., have been set out, so far, without results.

The usual heavy spat set of *P. vulgaris* and *P. sugillata* was experienced this summer. This set, however, was unusual in that these two species were mixed with a large percentage of *Electroma* sp. spat and in one instance *Electroma* spat outnumbered *Pinctada.* Observations from spatting plates spread over thirteen months indicate that the heaviest sets of *P. vulgaris* and *P. sugillata* occur in March. However, measurements of samples of young oysters grown from spat sets made during the last summer indicate that the set during the adjacent months is not negligible. Exact figures are not yet available.

From repeated measurements of a number of tagged specimens of *P. vulgaris* a growth curve has been constructed for the first eighteen months of life which shows clearly that the rate of increase of linear measurements is greatest in the first year, after which it decreases rapidly. From other observations it appears that maximum dimensions (except thickness) are reached in approximately two years. However, it must be remembered that these particular oysters were not under optimum conditions.

An attempt has been made to induce artificial fertilization of the eggs of *P. vulgaris.* No positive results were obtained, but the work is being continued.

Studies are being carried out on the plankton collected over the past two years with the objects of determining the abundance of *Pinctada* larvae and the general nature and abundance of the plankton in the area. It appears that *Pinctada* larvae are caught only in small numbers in standard plankton hauls.

9. HYDROLOGY.

(*a*) *Oceanic Investigations.*—Owing to the cessation of the activities of the F.R.V. *Warreen,* the oceanic traverses in south-western Australia cannot be maintained; only two such lines of stations were worked in the early part of the year, one off Albany and the other off Rottnest Island.

Monthly sampling at selected shelf stations in the south-east area was continued. In addition, a station was established off Ballina, on the north coast of New South Wales, in latitude approximately 29° S. It is considered that information should be obtained from north of the area of upwelling (Port Macquarie), as well as from the south.

In south-western Australia the newly established shelf stations were not worked as frequently as would be desired; nevertheless, it is apparent that the lack f nutrient regeneration observed in the shallow onshore aters is also pronounced at the shelf stations. This upports the theory that the onshore areas are isolated nd not subjected to sustained penetration of neritic ater, as in some parts of south-eastern Australia. More frequent sampling is required at the shelf stations o determine whether this penetration occurs at all.

(*b*) *Estuarine Investigations.*—Early in 1952 the stuarine programme was reduced in scale to allow for more intensive study of the methodology involved in he fundamental problems of estuarine productivity.

Several special surveys have been made in 1952 on he Hawkesbury River to determine the vertical temperature salinity profile of the system. At selected tations in the main channel samples have been collected at high water at metre intervals from the surface o the bottom and tested for salinity.

(*c*) *Oyster Hydrology.*—The attempt to estimate quantitative seasonal fluctuations in plankton populaions on the experiment lease at Shell Point proved unsatisfactory, and was abandoned at the end of 1951. The dry weight of plankton caught by pumping water through sieves of different mesh size was so small n all cases that the results could not be satisfactorily interpreted.

The collection of mud cores from selected stations in the intertidal zone was commenced in 1952; already it is apparent that there are sharply defined layers with distinct physical and chemical characteristics, such as percentage silt, pH, iron concentration, and free hydrogen sulphide. It is hoped that seasonal fluctuations in the distribution of these layers can be observed by the analysis of these cores.

Routine observations of mud and water temperature over the lease, as well as 24-hour surveys, were continued during the year.

In 1952, sediment traps were installed at different depths within the growing zone, in order to study the settling rate of silt which is stirred up from the mud surface by wind and tide. These traps consist of brass cylinders suspended vertically, the lower end being fitted with a filter paper pad on a fine gauze sieve, and the upper end with another sieve which allows fine particles to pass through during silt sedimentation. The material collected on the pad is analysed for organic carbon and nitrogen.

Routine sampling of the experimental tanks ceased shortly after the roof was blown off in a late winter gale in 1951. Variations in salinity became uncontrollable due to rainfall and evaporation. The roof was replaced and provided with windows on the northern slope. The effect of the addition of iron to the mud is now being studied; clean filings had to be used owing to the high cost of iron salts. The tank was drained and refilled with lease water every few days until the very high phosphate figure fell to normal, and the filings were added to the mud.

(*d*) *Fish Culture Investigations.*—Fortnightly collection of water and mud samples was maintained during the year at Maianbar, on the Port Hacking River. Four stations were established, two on the shallow flat and two in the deep lagoon. There is very little runoff into the system and stratification is not pronounced. Nevertheless there have been frequent periods of deoxygenation in the bottom waters of the lagoon, with the production of high phosphate figures. Similar high levels of phosphate have been detected on occasion in the shallow flat water; the mechanism of this phenomenon cannot yet be explained.

The core-sampling technique described in the previous subsection will be applied to the intertidal areas of Maianbar, to study the mud profiles and compare them with those at Shell Point.

(*e*) *Freshwater Hydrology.*—Sampling at Lake Dobson, Tasmania, continued during the year; the Government Analyst's Laboratory in Hobart has carried out the analysis of this material.

10. PLANKTON INVESTIGATIONS.

The plankton programme was redesigned so that sufficient data will be available to study the regional and temporal fluctuations of the composition, succession, and relative abundance of the plankton. Routine plankton hauls are now being made at hydrological stations off Port Phillip Heads, in Tasmania, and in Western Australia, and in New South Wales at Coff's Harbour, Port Macquarie, Port Stephens, Jibbon, Botany Heads, and Ulladulla. Two vertical hauls from 50 m. to the surface and a horizontal haul for fifteen minutes are taken at all stations.

Progress has been made with the sorting of the New Guinea plankton taken by the *Fairwind*. A publication on the plankton groups of the area is planned.

All plankton hauls are volumed (by the displacement method) as they reach the laboratory. Larger hauls are then subsampled and various methods are being tried.

An assay of the gross composition of the plankton from all stations on the east coast of Australia for the years 1948-51 has been made in an attempt to bring plankton information into line with hydrological data. This has shown *Thalia democratica* as the swarming salp in waters as far south as Bermagui, New South Wales, and in 1950 extending into the Bass Strait to the exclusion of *Ihlea magalhanica,* which is the swarming salp south from Bermagui and down the Tasmanian coast. This southern swarming form is usually the form occurring in the Bass Strait. *I. magalhanica* swarms in November and December, followed by swarms of *Iasis zonaria,* which persist in the plankton each year until May, and *Salpa fusiformis* appears occasionally in June-July. There are indications that the size of the salp swarm may inversely affect the richness of the crustacean euphausiid-dominated plankton which follows. *T. democratica* swarms without the apparent regularity of *I. magalhanica.* Rich swarms occurred in September, 1948, from Coff's Harbour to Jibbon, but were not detected off Ulladulla and Eden (sampling here, however, was not very regular in 1948-51). Salp swarmed off Ulladulla in April, 1949, and off Jibbon in March, 1950. Since Sheard in 1943-46 always observed biannual salp swarms off Jibbon, there is every indication, therefore, that sampling from Coff's Harbour to Eden in the years 1948-51 was very inefficient and that hauls must be repeated at not less than monthly intervals.

There are sufficient data to support Sheard's evidence of swarming *Nyctiphanes australis* during the disintegration of the salp swarms, especially in the hauls taken off Tasmania.

Apart from the temperature affecting salp swarms (salps swarming in September further towards the north, and in December towards the south), it is suggested that the salp swarms (which may be affected by oceanic offshore conditions) have a greater influence on the plankton succession and extent than hydrological conditions in the immediate area.

11. OTHER INVESTIGATIONS.

(*a*) *Microbiology.*—The microbiology of the intertidal estuary in relation to fish and oyster culture has received special attention. The aims of this study are the assessment of plant productivity and a detailed study of the mechanism of metabiotic and physicochemical changes in estuaries, with a view to assessing methods of increasing productivity. Such a project is calling for the united efforts of a team of workers, and the work of the past year has been of an experimental nature to determine the best methods to be used.

A monograph of the dinoflagellates in Australian waters has been completed. In the preparation of this paper, material from the plankton collections of C.S.I.R.O. has been supplemented by the Low Island collections examined by courtesy of the British Museum, the B.A.N.Z.A.R.E. collections, and material from the *Galathea* and the *Fairwind*. The oceanographic implications of dinoflagellate occurrences have been considered.

Bacteriological studies on marine and estuarine muds and sea-water continued, and results of the work from 1937 to date have been incorporated in a paper on heterotrophic bacteria in marine environments.

(*b*) *Algology.*—Before his resignation in April, the algologist presented two manuscripts, one on the ecology of Port Arthur and one on *Macrocystis* (giant kelp—source of alginic acid). The *Macrocystis* work was limited to two years. The taxonomy, biology, and distribution of *Macrocystis* have been described and an estimate has been made of the probable annual yield available for commercial purposes. Thirty thousand acres, the major part of the total distribution, were surveyed and estimated to yield an annual crop of 355,000 tons weed (wet) or 40,000 tons (dry), equivalent to about 8,000 tons of alginic acid.

(*c*) *Fouling by Marine Growths.*—A handbook of east Australian fouling organisms has been prepared for publication. This should be of use for the identification of the commoner foulers in the area. The analysis of data collected from an extensive field programme, now concluded after five years, is proceeding.

12. Acknowledgments.

The Victorian Department of Fisheries and Game has provided very generous laboratory accommodation in Melbourne for the Division's use.

In Tasmania the Department of Agriculture and the Police Department have assisted by hiring vessels for various important surveys.

Much valuable assistance has been given to the trout investigation work in Tasmania by the Salmon and Freshwater Fisheries Commissioners, who have made the services of their Hatchery staff available to carry out almost all of the fish marking and are now collecting information on the spawning runs at Lake Leake and in the Plenty River.

In Queensland the Division is continuing to operate from the Pearlshell research station in Thursday Island provided by the Premier's Department, and at Dunwich, on Stradbroke Island, at a station supplied by the Department of Harbours and Marine.

XII. FOOD.

1. General.

The Organization's research on food processing, preservation, and transport is undertaken chiefly by its Division of Food Preservation and Transport with main laboratories at Homebush, New South Wales, Brisbane, Queensland (meat investigations), West Gosford, New South Wales (citrus fruits), Eden, New South Wales (fish), Hobart, Tasmania (fish, apples and berry fruits), and at the Biochemistry Department, University of Sydney (physical chemistry). The work of the Division is described in Sections 2-12 of this Chapter. Work on the drying and processing of vine fruits is undertaken by the Commonwealth Research Station (Murray Irrigation Areas), Merbein, Victoria (*see* Section 13 below). Work on the manufacture of dairy products is carried out by the Dairy Research Section at Fishermen's Bend, Victoria, and is described in Section 15 of this Chapter.

Co-operative investigations on wines are carried out at the Waite Agricultural Research Institute (Section 14).

Division of Food Preservation and Transport.—Extension of the Division's work to Tasmania was planned in 1945, but only in the last year has it been possible to obtain laboratory accommodation. Two officers are now located at the Organization's Regional Laboratory, Hobart, and are studying problems associated with the processing of fish, apples, and berry fruits. It is hoped later to expand the facilities to include a large pilot plant for processing and a cold-storage block.

Since 1945, the Refrigerated Cargo Research Council has assumed the responsibility for the study of most problems of the shipboard carriage of foods in refrigerated cargo spaces. The Division has continued, however, to take an active interest in the Council's work. During the year, the Division has co-operated in an investigation of the rate of cooling and temperature distribution in a cargo of pears carried in two 'tween-deck spaces.

The Plant Physiology Unit operated jointly by the Botany Department, University of Sydney, and this Division was officially opened in June, 1952.

In conjunction with the Agricultural Research Liaison Section, a conference on the field control of peas for canning was held in Melbourne on 11th and 12th June, 1952. The conference was attended by representatives of three State Departments of Agriculture, fourteen pea canneries, and this Division. The subjects discussed were the production of pea seed, the analysis of the growing crop, and methods for the accurate prediction of optimum maturity.

Twelve technical papers by the Division's officers have been given at the annual conferences of Fruit Canners, the Institute of Food Technologists, the Commonwealth Cold Storage Association, and the Australian Institute of Refrigeration, and also at the Eighth International Congress of Refrigeration held in London in September, 1951. An officer attended the South Pacific Fisheries Conference in New Caledonia to advise on fish handling and processing.

Dairy Research Section.—The industrial background against which the work of the Dairy Research Section is conducted has continued to be one of stationary or diminishing total milk production in Australia, increased local consumption of all dairy products, greater diversity in manufacture, and slowly improving milk utilization.

Expansion of the Section to a size more competent to deal with the problems facing it has continued to be hindered by lack of accommodation. The Parliamentary Standing Committee on Public Works has reported favorably on the proposed establishment of new laboratories for the Section at Highett. Temporary additional accommodation is to be provided in a prefabricated building on the site.

2. Physics.

The Physics Section of the Division of Food Preservation and Transport has been concerned with several long-range problems on the storage and processing of foods referred to it by other Sections of the Division and also a number of shorter-term tasks of helping investigators with physical aspects of their chemical and processing problems.

(*a*) *Rail Transport.*—Several road tests on the new roof-tank refrigerator cars in New South Wales have been carried out in collaboration with the New South Wales Government Railways, using cargoes of chilled meat, frozen meat, and quick-frozen foods. These tests have provided enough data on the performance of the vehicles to formulate a set of rules for icing and alting for particular cargoes and journeys. The air-low pattern in these cars is different from what might be expected and some further study of it is likely to be profitable.

Tests have also been carried out on a new type of louvred van. This vehicle was shown to be almost identical in performance with the best of the older types.

(*b*) *Canning Processes.*—The fundamental principles have been considered further and a second paper on the subject has been published.

Work has continued on sources of error in using thermocouples for heat penetration measurements in cans during processing.

Some factors affecting the relation between experimental heating curves and theoretical curves derived from simple assumptions are being studied.

(*c*) *Calculation of Freezing Times.*—Plank derived approximate formulae for the calculation of freezing times of foods, making a number of simplifying assumptions. Difficulties were encountered in using these formulae to interpret experimental data, and the effect of the assumption that all the water is frozen at the initial freezing point is being examined.

(*d*) *Water Relations of Dried Vine Fruits.*—Experiments on the water relations of dried vine fruits have shown that it is doubtful whether true equilibrium is reached at low relative humidities. The behaviour of the material during the removal of water is being studied further.

(*e*) *Colour Measurement.*—After making tests on the performance of the photoelectric tricolorimeter, it has been decided to modify the electrical circuits so that the instrument will be more suitable for routine use. It shows promise in application to the grading of tomato pulp.

(*f*) *Design and Performance of Cold Stores.*—The experimental survey of fruit cool stores in the deciduous fruit growing areas of New South Wales, Victoria, and Tasmania has now been terminated. The records of observations in twelve different types of cool rooms have been examined.

(*g*) *Freeze Drying.*—The performance of the freeze drier was further examined, using ice, to determine the best operating conditions for the drying of troublesome materials such as peach and apricot purées.

3. Food Chemistry.

(*a*) *Anaerobic Destruction of Ascorbic Acid (Vitamin C).*—The studies on the anaerobic destruction of ascorbic acid are related to the loss of ascorbic acid from canned foods in which virtually anaerobic conditions are established within a short period after canning. The destruction is being studied at 30° C. and pH 2.2–6.0 over a period of two years. In citrate-phosphate buffers the rate was a maximum at pH 3. The rate was increased by fructose and even more by fructose diphosphate, particularly at the higher pH.

Furfural was obtained as a product of the reaction at pH 2.2–3.0. Variable amounts of carbon dioxide were also produced.

(*b*) *Natural Coating of Apples.*—The studies on the natural lipoid coating of apples are related to the physiological behaviour of stored fruit, as the natural coating is the main barrier to gaseous diffusion and hence influences the composition of the internal atmosphere. The chemical constitution of the oil fraction is being further investigated.

A further sample of fatty acids was separated by fractional distillation of methyl esters, and the major fraction was shown to be C18 unsaturated acids. Further information was obtained by determination of ultraviolet absorption, crystal form, and melting points of recrystallized fractions. Chromatographic separation of the unsaponifiable matter indicated the presence of hydrocarbons as well as unsaturated alcohols.

(*c*) *Volatile Products of Apples.*—The organic volatile substances produced by fresh apples are concerned in the aroma and probably also in the control of ripening. There is evidence of some relation between volatile substances and superficial scald, a functional disorder.

The volatile carbonyl compounds produced by whole Granny Smith apples were identified as acetaldehyde, propionaldehyde and acetone. A paper was prepared for publication. A volatile fraction of the natural coating was separated by distillation, and this fraction and other volatile substances are being tested for their possible effect on superficial scald.

(*d*) *Arginine-Fumaric Acid Reaction in Peas.*—Some work was carried out on a recently isolated enzyme system in peas, which catalyses a reaction between arginine and fumaric acid. The reaction product was purified and its chemical nature studied. The specificity of the reaction was investigated.

(*e*) *Determination of Ethylene Dibromide.*—The determination of ethylene dibromide (which is used for fumigating citrus) in air was investigated for the Fruit Section.

(*f*) *Electrophoresis.*—In collaboration with the Division's experimental workshop the construction of the electrophoresis apparatus has been practically completed. Every care has been taken in the design of the apparatus to make it as sensitive as possible, in order to extend the range of usefulness of the moving boundary method.

(*g*) *Micro-Kjeldahl Determination of Nitrogen.*—In the protein preparative work of the laboratory and in work on the extraction of fish-muscle proteins, it is essential to have an accurate and rapid method for the determination of nitrogen. To this end a systematic study has been made of the effect of a mercury catalyst on the digestion of nitrogen compounds. The use of hydrogen peroxide in these digestions has been extensively studied. This has resulted in a procedure suitable for even the most refractory heterocyclic amino acids. A suitable distillation apparatus for this method has been devised and development of a more rapid procedure in which the distillation is eliminated is progressing satisfactorily.

(*h*) *A.C. and D.C. Polarography.*—Polarography has continued to be a very useful research tool and method of analysis in the work of the laboratory. In research it has been used extensively in the investigation of the combination of amino acids with heavy metals; and in analysis it has been used in the determination of "trace" elements in canned foods. To facilitate the accumulation of polarographic data a D.C. recording polarograph that plots maximum currents rather than average currents is being developed in collaboration with the Division's Physics Section. An A.C. polarograph of considerably increased sensitivity is being constructed.

(i) *Chemical Reactions in Processed Foods.*—Shortage of staff made it necessary to concentrate during the year on one aspect only of this project. For this reason, the work was confined to a study of the composition of certain raw fruits as a basis for future work on the browning of these fruits when dehydrated and stored. The sugars in each of a number of samples of apricots, peaches, pears and apples were studied by means of one- and two-dimensional paper chromatograms. A ketose occurring in apricots could not be identified even tentatively by these methods.

Its reactions are being studied and work is in progress to isolate larger amounts of this sugar by means of ion-exchange and charcoal columns. Some progress has also been made in the identification of the amino acids and other acids occurring in these fruits.

4. MICROBIOLOGY OF FOODS.

Investigations continue mainly with a study of those environmental factors which affect the growth or death of food-spoilage micro-organisms. Problems of the diagnosis and control of spoilage arose fairly frequently but, with one exception, each required only a small amount of experimental work. The exception involved assistance to a manufacturer experiencing yeast spoilage in a carbonated fruit-juice beverage.

(*a*) Clostridium botulinum *Investigations.*—Experimental work on the temperature relations of types A and B of this organism, which produce dangerous toxins in foods, has been completed and the results are being prepared for publication. A similar study on 10 type E strains is not yet complete, but the results show substantial differences from those obtained with types A and B. This finding is a strong suggestion that type E strains have a different natural habitat from the other two types.

(*b*) *Heat Resistance of Bacterial Spores.*—Knowledge of factors affecting the destruction of bacterial spores by heat is of vital importance where, as in canning, heating is used to preserve the food. Earlier work in this and other laboratories has shown that germination of the spores may be impaired by low concentrations of fatty materials. Some chemical determinations of the fatty substances in nutrient media have been made in order to determine whether these are present in sufficient quantity to account for the observed inhibitory properties of the media. The amounts found were very small, but the experiments are being repeated with additional refinements. Experimental work in this field is now being resumed more actively following the return of the investigator from a two-year period of study in England.

(*c*) *Water Relations of Micro-organisms.*—The ability of micro-organisms to grow on various foods depends, amongst other things, upon the availability of water. This environmental factor has not received a great deal of study hitherto, except in relation to certain moulds that may grow on dried foods. Studies of the rates of growth of various organisms have, therefore, been made under controlled conditions of water activity. The results obtained allow useful predictions to be made regarding the abilities of different organisms to grow in various foods. Experiments with twelve strains of *Staphylococcus aureus* and sixteen strains of *Salmonella* have been almost completed at 30° C. The results will be useful for defining conditions which will prevent the growth of these important agents of bacterial food poisoning. Other studies have been made with fungi that are capable of growth under relatively dry conditions. There are wide differences in the water requirements of the different organisms studied, and an attempt is being made to obtain an understanding of the methods by which the microbial cells gain water from their surroundings.

(*d*) *Mould Wastage of Stored Fruit.*—Work in this field was continued by the investigator stationed at the Botany Department in the University of Melbourne. The experiments were confined mainly to a study of the diffusible toxin liberated by the fungus *Sclerotinia sclerotiorum.* The principal toxic substance was found to be oxalic acid and its salts. The conditions under which oxalate is liberated and its capacity to promote leakage from carrot tissue have been described in a note which has been accepted for publication.

The experiments on metabolism of fungi and the activity of diffusible toxins required improved quantitative procedures for identifying and estimating small quantities of several organic acids. Some improved methods have been devised and the results incorporated in two papers which have been submitted for publication. Owing to the resignation of the investigator the work has been discontinued.

Workers at the Homebush laboratory have co-operated with officers of the Citrus Research Laboratory at Gosford, New South Wales, in determinations of the surface microflora of oranges and their relation to the incidence of green mould wastage in stored fruit.

(*e*) *Mould Counts of Tomato Products.*—A standard method for the enumeration of mould fragments in tomato products is widely used and accepted as a method of quality control, large amounts of mould being an indication that large amounts of unsound fruit have been used during manufacture. The estimates made with the standard method are, of course, subject to error, and some experiments have been undertaken to obtain a measure of the relative importance of the various sources of error. The results should determine the most economical way of achieving a specified level of confidence in estimates of the mould count.

5. MEAT.

(*a*) *Co-operative Investigations.*—(i) *General.*—The co-operation between the Brisbane Laboratory, the Low Temperature Research Station, Cambridge, and the British Ministry of Food has been maintained, and the exchange of information has been facilitated by the visit of a senior officer of the Brisbane Laboratory to England. The results of the English studies on the two experimental shipments of frozen beef are now complete and it is expected that a report will soon be issued covering this and corresponding Australian work.

To speed up the work, two research officers from the Low Temperature Station are being seconded to work in the Brisbane Laboratory and additional laboratory facilities are being provided.

(ii) *Frozen Storage Experiments.*—The comparison of the effects of storage of beef quarters at —13° C. and —18° C., which was begun last year, has been extended to twelve months' storage and the results of the full storage programme analysed. It is hoped to publish the results in the near future.

A further experiment on beef quarters has been laid down in which the effect of storage at —13° C. and —18° C. is compared in material frozen rapidly and slowly.

The results of this work should make it possible to establish the best processing conditions to use if it should be found advisable to accumulate stocks of frozen meat during glut periods to carry over the period of short supply.

(iii) *"Drip" Investigations.*—As a result of work in Brisbane and in England the importance of the amount of fat in meat in controlling the extent of "drip" from thawed beef is being realized. This aspect is receiving further attention.

(*b*) *Muscle Physiology.*—Further study of the method of estimating glycogen in muscle has revealed the existence of errors due to solubility of glycogen in the precipitating solution and to destruction by the caustic potash solution used to dissolve the muscle tissue. The magnitude of these errors is now being investigated quantitatively and alternative procedures are being tested. Studies on glycolysis in ox muscle have been held up until the method of analysis is improved.

(*c*) *Air-borne Contamination.*—The existence has been established of at least two distinct mechanisms which contribute to the death of bacteria that are air-borne in chilled storage spaces. These mechanisms operate selectively at high humidity (90 per cent.) and low humidity ((50 per cent.) and the sensitivity of bacteria to them has been shown to vary with the bacterial type, physiological condition, &c. At intermediate humidity (70 per cent.), the death rate of all types of bacteria examined is low and at such humidity the transfer of bacteria in cool stores is potentially at a maximum.

(*d*) *Ozone Sterilization.*—A detailed study of the rate of decomposition of ozone has been made and the influence of materials such as meat on the rate of decomposition has been measured.

The study of the effect of different concentrations of ozone on the growth of organisms likely to be present in meat has been continued.

(*e*) *Freezer Burn Studies.*—To investigate the influence of removal of water from frozen offal on the so-called "freezer burn", improved equipment has been developed to measure evaporation from frozen offal under carefully controlled conditions. Equipment has also been developed to study rates of freezing of offals, especially under conditions of good heat transfer between the cooling medium and the offal.

6. Fish.

(*a*) *Chemical Methods for Estimation of Spoilage.*—A rapid laboratory or field method for estimation of volatile bases in fish muscle, by a modification of the Conway technique, has been developed. Further work has been done on the problems of heat-breakdown of urea and trimethylamine oxide in fish flesh, and attempts have been made to relate these chemical changes to the development of particular flavours in canned fish.

(*b*) *Other Investigations.*—Studies on the development of black staining during storage of cooked prawns have indicated that the condition is brought about by enzymic changes involving tyrosine and/or the "dopa" system in the blood of the prawns.

Preliminary work has been carried out on the nature of the post-mortem changes in the muscles of Tasmanian scallops and their possible relationship with the texture of the flesh.

Observations have been made on the influence of various pre-processing treatments on the quality of canned fish and on the development of "curd".

7. Eggs.

A comparison has been made of the effects of storage at 1° C. of eggs held in various tensions of carbon dioxide and of oiled eggs held in air. A range of carbon dioxide concentrations was chosen to obtain pH levels in the whites similar to those obtaining in oiled eggs. The results of physical and chemical examinations of the eggs after storage for three and six months are now being analysed.

Experiments have been continued on the relationship between the pH level and the total carbon dioxide content of egg whites. The results again indicate that, at a given pH level in the white, oiled eggs generally contain more carbon dioxide than egg white which has been equilibriated with carbon dioxide.

Further studies have been made on the substance causing pink whites in stored eggs. The active principle in the plant genera *Malva* and *Gossypium* is associated with the fatty acids, but as it is extremely labile, it is proving difficult to isolate and identify.

8. Fresh Fruit and Vegetable Storage and Transport—Plant Physiology and Biochemistry.

The work of the new Plant Physiological Research Unit has particular reference to the behaviour of cells and tissues and helps to provide a background of knowledge required for proper understanding of fruit and vegetable storage problems.

Since the successful storage of fruits and vegetables depends on maintenance of cell contents, part of the unit's work is concerned with the properties of the cell surface and its absorbing capacity. These are being investigated by the technique of electrophoresis on cell contents freed from the cell wall. The physiology of water uptake by plant cells is also being investigated and the permeability of the plant cell membranes is being studied with beet tissue. Investigations are in progress on the effect of 2,4-D and other growth substances on respiration and on processes, such as salt accumulation, coupled with respiration.

In the work on the relation between salt accumulation and respiration, particles known as mitochondria have been isolated from beet, carrot, and apple tissues, and shown conclusively to contain the enzymes cytochrome oxidase and succinic dehydrogenase. In collaboration with the Division of Industrial Chemistry, these particles have been shown, by the electron microscope, to be approximately spherical; their size after extraction varied with the osmotic pressure of the extracting solution. The characteristics of these particles have been investigated thoroughly and defined, and some evidence for enzymes other than succinic dehydrogenase and cytochrome oxidase on the particles has been obtained. The influence of phosphate on their activity has been examined and it has been shown that actively respiring particles accumulate phosphate. The relationship of the particles to other ions in the solution is being investigated.

Since the development of fruits under different conditions has a profound effect on their subsequent behaviour in storage, the physiology of growth in apple fruits is being studied. The work on the development of apples on the tree over three successive seasons has been completed and a paper has been prepared confirming the main conclusions published earlier and extending our knowledge beyond normal commercial maturity.

Work on nitrogen metabolism has continued and the soluble nitrogen constituents of developing apples have been examined during two seasons. The free amino acids increased in amount from time of blossom until after commercial maturity but the same acids were present throughout. Similar amino acids were found in the leaves and in the protein of both leaves and fruits. It has been shown that late in the life of the fruit a considerable increase in soluble nitrogen is accompanied by an increase in amide nitrogen.

The sudden rise in respiration at ripening, known as the climacteric, has been investigated in apples. A new theory suggested for this rise in a recent paper has been tested in the current season. The rise was attributed to an increased demand on respiratory energy to maintain the increased unstable protein in cells above a certain size. A test of this hypothesis has given results consistent with the theory. A large increase in extractable succinic oxidase has been shown to accompany this rise in respiration.

The relation of fruit size to cell size and cell number was further studied because of the importance of the factors controlling fruit size in relation to storage. The collaborative work with the Division of Plant Industry in Hobart, Tasmania, on fruit size, is reported in Chapter III., Section 5. The cell size and cell number of a few fruits from the west coast of America were compared with those of fruit of the same variety and comparable size grown in New South Wales.

An officer of the Division, stationed temporarily at Cambridge, England, has been studying the processes of phosphorylation by enzyme systems of higher plants and their relation to synthesis.

9. Fresh Fruit Storage and Transport—Technology.

Work on storage and transport has been continued in collaboration with the New South Wales Department of Agriculture. A particularly active programme has been carried out at the joint laboratory, the Citrus Wastage Research Laboratory at Gosford, where most of the work on citrus is conducted.

(*a*) *Skin Coating.*—Four papers dealing with the effects of wax or oil emulsions applied to the skin of apples have been prepared for publication.

(*b*) *Orchard Variability.*—Earlier reports have described the work on variability in storage behaviour in the apple varieties Delicious and Granny Smith, which was carried out over five successive seasons. This work will make possible the comparison of fruit of different sizes from different trees, from different orchards, and from different seasons. A statistical analysis of the large quantity of data accumulated is a major task and is being carried out by the Section of Mathematical Statistics.

(*c*) *Maturity—Number of Days.*—The experiment to test whether the number of days from full blossom could be used as the best criterion of maturity for picking apples for long storage, was carried out in conjunction with the orchard variability experiment. This also required lengthy statistical examination. There is no indication that the method will be better than the recommended method, which is the change in ground colour, used in most districts of Australia.

(*d*) *Temperature of Storage.*—As a result of the improvement in temperature control in recent years in commercial stores, it has become possible to store fruit at lower temperatures with less risk of freezing. The effects of lower temperatures on the storage life of apples is therefore being investigated.

(*e*) *Delay before Storage of Pears.*—Because of the difficulty in many Australian districts of obtaining rapid storage and cooling of pears, the effects of delay and rates of cooling or storage life and respiration of William Bon Chrétien and Packham's Triumph varieties are being investigated. The results tend to confirm the earlier work which showed that the shorter the delay, the better the subsequent storage life; an attempt is being made to define more precisely the effect of a given delay on storage life.

(*f*) *Rotting in Winter Cole Pears.*—Blue mould and grey mould have given some trouble during commercial storage of this variety. Various methods of improving storage life, including the use of pre-harvest field sprays, careful handling and post-harvest dips are being investigated.

(*g*) *Storage of New Varieties of Stone Fruits.*—Work on the storage qualities of new varieties of peaches and plums grown on the Bathurst Experimental Farm has been continued.

(*h*) *Storage for Canning.*—An experiment on freestone peach varieties to determine storage life and effect of storage period and controlled ripening on ease of peeling and subsequent canning quality was carried out in conjunction with the Canning Section. With one clingstone peach variety the effects of pre-storage conditioning and controlled ripening on canning quality were investigated.

(*i*) *Orange Storage.*—The borax, boric acid, and wax process (known as "Keepswell" process) continued to give good results in control of wastage due to green mould. The effects of varying levels of borax and boric acid and of the diluting by wet fruit entering the waxing tank have been investigated. Experiments on delay between picking and processing have continued.

A comparison of the effect of pulling and clipping on mould wastage in Navel and Valencia oranges showed that with more mature Navels and with Valencia oranges harvested at three different maturities, clipping greatly reduced green mould wastage as compared with pulling.

(*j*) *Lemon Storage.*—Experiments on the shed storage of lemons have shown that a post-harvest dip of the growth substance 2,4-D gave excellent results in control of stem-end rots; used in conjunction with preharvest field applications of Bordeaux mixture it promises to be most effective.

(*k*) *Fungicides.*—Tests with new fungicides on citrus fruits for green mould control have been continued. Nothing as effective as borax as a dip has yet been obtained, but this "screening" of new compounds will be continued. Preliminary trials with diphenyl wraps have given promising results.

(*l*) *Spore-load Investigations.* — In collaboration with Dr. T. B. Kiely, of the New South Wales Department of Agriculture, the influence of known levels of loading with spores of green mould on subsequent wastage in Washington Navel oranges was investigated. This study will help to define the relative importance of different factors in handling oranges. Increase in concentration of spore load applied in aqueous suspension caused significant increases in wastage in subsequent storage. Methods of reducing natural spore load per fruit are also under investigation.

(*m*) *Detergents and Waxes.*—Comparison of a number of detergents for removal of sooty mould and sooty blotch have shown no more efficient or economical type than the sodium silicate type normally used. Trials with citrus wax emulsion imported from the United States of America did not indicate any advantage over local materials now in use.

(*n*) *Orchard Varieties and Storage Behaviour.*—In collaboration with the Irrigation Research Station, Griffith, samples of Washington Navel oranges taken from farm block 466 were cool-stored at Homebush. Fruit from different trees which had been subject to differences in soil type, cultural method, levels of nitrogen fertilization, and levels of irrigation were stored and some differences in degree of wastage were noted. The results are being analysed statistically and the experiment is being repeated.

(*o*) *Control of Fruit Fly.*—Work on vapour heat treatment to destroy fly eggs and larvae in freshly picked fruit has been continued, and the plant has been adapted to undertake investigations of the effects of fumigation with ethylene dibromide, another effective method. Work has been almost entirely confined to the effects of the two treatments on the fruit and its subsequent storage behaviour. A few experiments have been carried out in collaboration with entomologists of the New South Wales Department of Agriculture to determine the effect on the insects themselves.

10. Canning and Fruit Products.

(*a*) *Vegetable Canning.*—In 1945 pea-canning investigations were begun to find means of improving the quality of the Australian product. The work has centred mostly about control of the growing crop, because the relation between quality and maturity at picking was well known but not completely understood. A rapid method of measurement of maturity was obtained by development of the maturometer, an instrument that records directly in pounds pressure the force necessary to puncture a sample of raw peas. The maturometer was patented by C.S.I.R.O., and is now being produced commercially under licence.

Maturometer measurements were made on samples of ungraded peas taken at successive stages from pea crops during periods up to two weeks before harvest. The results showed that it is possible to estimate the maturity of any particular crop on any given day during the final growth period. These samples, when divided into size grades and maturities of each grade etermined, indicated that it was possible to detect the ay on which the maximal yield of best quality peas is btained. This day has been termed the "date of ptimal harvest", and the maturometer reading of he ungraded sample has been called the "Maturometer Index" (M.I.).

Over the last three years the investigations have een directed towards finding the rate at which a pea rop matures, since ability to predict in advance the ate of harvest would be of great value to the canner. The maturation rate was found to be of the order of 0 M.I. per day, thereby providing the link between he maturity of a crop at any point and the date f optimal harvest, which has been determined as M.I. 50. The harvesting of commercial crops in Tasmania nd New South Wales was controlled by officers of his Division during the 1951-52 season, using these esults as a basis. Accurate control was achieved, hereby confirming in practice the previous experimental findings.

There are preliminary indications that it will be possible to predict the weight of cut vines to be transported to the vining station, and the yield of peas to be handled in the cannery. Work is also in progress to ind with more accuracy than hitherto the growth period in days from planting to harvest so that sowings may be spaced in such a way that an even flow of peas to the cannery is assured.

Previous work with asparagus showed that delays up to three days between cutting and canning have no detectable effect on the quality of the canned product, even when the spears are held on the cannery floor without refrigeration. This result suggests that asparagus may be hauled over long distances from the growing area to the cannery. During 1951 observations were made on commercial loads of asparagus transported 45 miles by road to Batlow, New South Wales. Temperature measurements at a number of points in the load demonstrated a marked self-heating effect. It is therefore recommended that attention be paid to the method of stacking of loads to ensure adequate ventilation through the stack during transport.

Investigations were continued into means of improving the texture of canned cauliflower. A series of pre-canning treatments, which consist of immersion of the vegetable in salt solutions at carefully controlled temperatures for varying periods of time, were shown to have an appreciable firming effect on texture. An instrument has been constructed for the quantitative measurement of firmness in the experimental canned material.

Breeding work aimed at producing a tomato with satisfactory canning characteristics was carried on. Twenty selections from the 1951 trial, fifteen first generation hybrids, and two standard canning varieties were tested. The variety Rouge de Marmande was found to possess many desirable canning qualities, and is a parent of most of the selected crosses.

The development of the mechanical bean harvester in the United States of America has emphasized the need to investigate beans on the basis of a one-pick crop. The programme of work being conducted is, therefore, similar to the work with canning peas. A detailed analysis was made of a crop of Landreth Stringless variety from the point of view of yield of size grades in relation to maturity. The maturometer was adopted for the rapid measurement of maturity. It is possible that an optimal picking date may be defined, and that prediction methods may be capable of application.

(*b*) *Fruit Canning.*—The rise in the popularity of canned freestone peaches in the United States of America prompted investigations into the most suitable Australian varieties and into appropriate canning methods for this type of pack. Initially all promising varieties were included in canning trials, but the number tested has been steadily reduced. It was shown that four freestone varieties, viz., J. H. Hale, Blackburn, Success, and Halehaven, possessed the requisite canning characteristics. Cool storage tests designed to extend the canning season were conducted with J. H. Hale and Blackburn. These varieties were also used in an investigation of peeling techniques.

Quality improvement work with cling peaches by careful control of maturity was advanced a further stage. Golden Queen variety was used in an investigation of the value of a number of pre-storage ripening treatments.

An extensive apple canning programme aimed at improving the quality and presentation of canned solid pack apple was carried out in Tasmania. Treatments included firming for retention of shape, water uptake, and blanching methods. The work is being continued.

(*c*) *Fruit Juices.*—Navel oranges, which comprise approximately half the Australian orange crop, are unsuitable for the production of canned orange juice because of a characteristic bitterness which appears during pasteurization. This bitterness is caused by a bitter principle, limonin, which is the subject of chemical studies directed towards the elucidation of its molecular constitution. Limonin appears to be a rather unusual compound having two carbocyclic rings, two lactone rings, and three oxygen rings of the nature of cyclic ethers or acetals. From the results of degradation reactions and ultraviolet and infrared spectral data, it has been possible to postulate a number of partial structures for the limonin molecule.

A practical solution to the problem of bitterness in Navel orange juice is more likely to be found in the choice of rootstocks. Canning experiments extending over two seasons indicate that bitterness does not appear in the juice of Navel oranges grown on *Poncirus trifoliata* rootstocks. Tangelo and Cleopatra mandarin rootstocks are also probably satisfactory in this respect.

(*d*) *Container Investigations.*—Tinplate allocations to Australia now include considerable quantities of electrolytic tinplates having lower tin coating weights than hot-dipped plates. It was necessary to test the performance of electrolytic cans as containers for Australian canned foods. Experimental packs of four representative foods, peaches, pears, tomato juice, and sweet corn, have been incubated for fifteen months at 38° C. Examination of these packs indicates that electro-tinplate, when protected with suitable lacquers, is equal to or better than hot-dipped plate in corrosion resistance.

Electro-tinplate has also been tested in the form of closures for glass containers for a number of products. It was found that there was no difference in corrosion resistance between matte-finish and melted-finish electro-tinplates of the same tin-coating weight, whether plain or lacquered.

Internal lacquers for food cans tested during the year included seventeen acid-resisting and five sulphur-resisting lacquers. Some of these lacquers were developed by Australian manufacturers in the course of continuing research programmes directed towards improved performance, while others were formulations modified because of restricted availability of imported resins.

In an attempt to elucidate the mechanism of "sulphur-staining" in food cans, methods for the determination of the sulphydryl group in foods are being critically examined.

(*e*) *Equipment.*—Experimental investigations previously reported showed that rotation of cans during heat processing effected marked improvement in product quality through reduction in time. The advantage of this procedure in comparison with the "still" cook was most noticeable in liquid packs of a viscous nature, e.g., rotary cooking was found to reduce the heating time of tomato pureé to one-thirtieth of that required by the standard method. The conventional 1 lb. tall can was used for this work.

During the current year observations were made on the No. 10 can of approximately 6 lb. capacity. Passionfruit pulp was raised from 21 to 88° C. in slightly less than two minutes, as compared with 29 minutes by the "still" cook process.

The existing thermorotary cooker operates at atmospheric steam pressure and is therefore capable of handling only fruits and fruit products. A pressure cooker has been designed to obtain data on packs of vegetables and other low-acid products.

11. Dehydrated Foods.

(*a*) *Vegetables.*—Techniques of the application of starch coatings to dehydrated carrot have been investigated. Carrot is one of the most unstable dehydrated products and earlier English and American work suggested a general improvement in quality by starch coating. This view is corroborated.

The presence of starch on the surface of carrots adds to the difficulty of removing the material from drying trays. Consequently a silicone tray coating was tested. Marked improvements in the removal of potato strips from the trays was noted but the coating had little effect on the removal of carrot or cabbage. This was presumably due to the higher sugar contents of the last two vegetables.

Packing in an inert gas in a recognized method of improving the storage life of dehydrated vegetables. Many of the conditions for gas packing are vague, and equipment has been set up and some of the techniques studied to elucidate some of these details.

(*b*) *Fruit.*—The installation of a tunnel in which the sulphuring of fruit before drying may be investigated is in progress. Controllable variables in the experiments will be sulphur dioxide concentration in the air stream, temperature, and air speed. At present, sulphuring in commercial plants is a haphazard process and it is hoped to put it on a sounder basis.

At the request of the Department of Commerce, centre temperatures were determined in apricots and peaches during dehydration. Normally, conditions were such that insects would be destroyed by the procedure.

(*c*) *Dehydrated Sugared Fruit.*—Studies on the storage life of sugared fruit were continued, particularly to obtain the minimum sulphur dioxide level at which a reasonable storage life is possible. It appears that deterioration is very rapid when only 100 p.p.m. of sulphur dioxide is present initially.

Multiple soaking of fruit in syrup appeared to have little advantage over a single soak.

Temperature of drying was investigated and initially there appeared to be no difference between samples dried at 55° C. and at 71° C.

Investigations on the re-use of steeping syrups were continued and procedures were worked out for adjusting the composition and concentration of syrup and the concentration of metabisulphite in the syrup. Initial quality did not appear to decrease with continued re-use of syrup.

(*d*) *Meat.*—The experiments on the storage of dried mince prepared from mutton carcasses have been continued.

A systematic study of the preparation and storage of sliced, dried mutton has been undertaken. The slices, though fragile, are of good initial quality, but the storage life is less than that of mince.

12. Frozen Fruits and Vegetables.

Investigations on the freezing of fruits and vegetables are conducted jointly with the New South Wales Department of Agriculture. A major part of the work has been devoted to studying the effect of raw material quality on the frozen product. The questions of suitable harvesting maturity and choice of correct varieties for freezing have received special attention. The effects of methods of handling raw material, of preparation, and of packaging have been studied using many fruits and vegetables.

(*a*) *Fruits.*—The testing of varieties of freestone peaches has been continued. Several yellow-fleshed varieties which had given good results in previous work again proved very satisfactory. Samples of one variety obtained from three different localities gave products which did not differ significantly.

It has been shown in overseas work that the degree of browning in sliced frozen peaches is related to the tannin content. Preliminary work on the method of estimating tannin has been completed and some data for different varieties have been obtained.

Frozen fruit is usually stored at a temperature of —18° C. when storage periods of up to one year are expected. It may, however, be necessary to hold for short periods at higher temperatures, e.g. during sea transport. Some preliminary investigations on frozen pineapple were made and it appeared that holding for as long as twelve weeks at —10° C. did not have any noticeable effect on quality. Further work will be necessary before any definite conclusions can be drawn.

(*b*) *Vegetables.*—The testing of pea varieties has been continued. Several varieties investigated have given frozen products of very good quality. Further data on the relation between maturity and quality have been obtained. It is now possible to define more closely the range of alcohol-insoluble solids (an accepted index of maturity) which corresponds with good quality in frozen peas.

Certain problems of off-flavour and skin toughening in peas are known to be associated with the handling of raw material. The effect of time and temperature on the development of these defects has been further studied.

Work on the maturity of beans of the "string" and "stringless" type showed that a satisfactory pack could be prepared from a wide range of maturities (as measured by percentage seed and fibre) in "stringless" beans. However, with "string" varieties the frozen product became unacceptable at an early stage of maturity when the first sign of "string" appeared.

The effects of variety, maturity and blanching methods of cauliflower, broccoli and Brussels sprouts have been investigated.

13. Dried Vine Fruit.

(*a*) *Fruit Processing.*—The use of fatty acid esters, or related compounds containing a paraffin chain of suitable length with a polar group at one end, in the cold-dip process for sultana drying has been investigated further. Improved commercial oil emulsions have been produced containing suitable proportions of fatty acid ester and sulphonated fatty ester. Such emulsions gave faster drying rates of sultanas subjected to cold-dipping trials last season than had previously been obtained.

Beneficial results in the mixed dip process for sultana drying were also found last season in trials of the use of suitable mixtures of ethyl oleate and oleic acid instead of vegetable oil and oleic acid.

(*b*) *Sultana Drying.*—At the request of the Bureau of Agricultural Economics, Department of Commerce and Agriculture, an investigation was undertaken on the relative economics and efficiencies of sun-drying on individual holdings, dehydration at central establishments, and dehydration on individual holdings. Commercial dehydrators made available by the Red Cliffs Co-operative Packing Co. were used.

It was clearly established that dehydration was coniderably more costly than sun-drying and the product s of inferior colour and general quality.

For dehydration on individual holdings it would be necessary to design reasonably cheap and portable quipment for use with existing racks, embodying a ource of heat, an air-circulating fan and ducts, and a prime mover. Such equipment would enable fruit o be finished after partial sun drying or dried from he fresh fruit stage when weather conditions are unfavorable. By enclosing racks with suitable side curtains it has been found in trials at Woorinen and at the Merbein Station that dehydration of rain-damaged sultanas can be effected in 48 hours from the fresh fruit stage.

14. Wine.

The investigations directed by the Committee on Oenological Research, which comprises representatives of the Organization, the Federal Viticultural Council, the Australian Wine Board, and the University of Adelaide, have been continued at the Waite Agricultural Research Institute.

(*a*) *Sherry Investigations.*—The effects of various factors on the growth of the flor yeasts and on the changes which they bring about in wines have been studied and an account of the results so far obtained is being prepared for publication.

Further investigations concerning the relationship of the sulphur dioxide content of wine to the growth and metabolism of the flor yeasts are in progress.

Two authentic cultures of flor yeasts obtained from Spain have been tested in the laboratory and in three wineries. In these tests, one of the new strains was superior to the best strains already in use in this country.

(*b*) *Wine Yeasts.*—The laboratory testing of the wine yeasts in the culture collection has been completed. However, the investigations have shown the desirability of developing improved techniques for testing yeasts in the laboratory and work is proceeding along these lines.

An important requirement of the Australian wine industry is a yeast which will function efficiently under the high temperatures sometimes experienced at vintage time. Since none of the yeasts at present in the collection has been found to have this characteristic adequately developed, work has started on the development of suitable strains by habitation procedures.

15. Dairy Products.

(*a*) *The Utilization of Skim-milk Solids.*—One of the most effective methods of bringing about a nutritionally satisfactory level of milk solids consumption by the community is to add dried skim milk to bread. Work on this project has been continued at the Bread Research Institute in Sydney. The addition of glyceryl monostearate and potassium bromate to skim-milk powder improves the physical as well as the nutritive quality of bread. It was, however, found impossible to obtain a consistently satisfactory result in drying this material and the drying difficulty was overcome by the replacement of 75 per cent. of the glyceryl monostearate by hydrogenated stearin. The modified product was equally satisfactory and the fat mix was readily dispersed and resistant to oxidation.

The substitute for egg-albumen previously developed was improved by treating the skim-milk concentrate with calcium hydroxide for an extended period at low temperature, which made the addition of other foam-stabilizing materials unnecessary. The substitute will replace egg-albumen in all its normal uses except nougat-type recipes.

Development of a whole-egg substitute for use in sponge cake is proceeding, the immediate object being the replacement of 50 per cent. of the eggs in a standard recipe. Skim-milk concentrate treated with either sodium hexametaphosphate or trisodium citrate and sodium carbonate before drying has given promising and reproducible results.

(*b*) *Oxidized Flavour in Milk.*—Oxidized flavour is one of the most serious flavour defects in liquid milk. Continued investigation has confirmed that the type of oxidized flavour induced by traces of copper comes partly from the oxidation of the milk fat and partly from reactions in the non-fat phase. These latter reactions give rise to the "cardboard" element in the flavour, and work is at present being directed to the isolation and if possible the identification of the chemical compound responsible. The compound is steam volatile and some progress has been made in its purification, but the quantities obtained are minute.

Milk reconstituted from fresh skim milk and butterfat does not develop oxidized flavour even in the presence of several parts per million of copper. This resistance to oxidation is lowered if a surface-active agent such as glyceryl monostearate is present. Other evidence also suggests that the oxidation in both fat and aqueous phases is greatly influenced by the particular physico-chemical condition of the materials adsorbed at the fat globule surface.

A paper covering part of the work has been accepted for publication.

(*c*) *Susceptibility of Fat to Oxidation.*—Since current production is now at some seasons insufficient to meet local consumption, the selection of butter suitable for cold storage has become increasingly important. Overseas work has indicated the contents of tocopherol and conjugated unsaturated fatty acids are related to the susceptibility of butterfat to oxidation. Suitable methods have been developed in the Section for pursuing this line of research, which may also bear on the seasonal variation in susceptibility of whole milk to oxidized flavour.

(*d*) *Flavour Chemistry of Australian Cheddar Cheese.*—This project forms part of a general study of the chemistry of the substances responsible for the flavours of Australian dairy products. Much time has necessarily been devoted to the development and improvement of methods and equipment for the isolation, purification, and identification of the minute quantities of chemical substances involved. Paper partition chromatography has proved very effective in the identification of fatty acids and of alcohols, aldehydes, and esters, which must first be converted to the acids. Column chromatography has been used in separation and estimation of the volatile acids. An apparatus automatically recording the refractive index of eluates has been constructed. Much attention has also been given to the techniques of flavour judgment on the compounds isolated.

The relative quantities of the various fatty acids in Australian cheese of low and of high quality have been studied.

(*e*) *Structure of Dairy Products.*—The chemical and physical structure of the fat globule membrane controls many important phenomena in dairy processing, and this structure is not known with any certainty or clarity. An extensive review of literature has been undertaken. Experimental techniques are difficult to devise. Observations of the behaviour of fat globules on the surface of milk under the action of capillary active substances and fluorescent staining of the fat phase have been used. Structure studies have been made on butter concentrate and on milk powders of various types.

The occurrence of texture defects in Australian butter, which arise from incorrect microstructure, have been statistically examined from export gradings. Only 2.6 per cent. of factories in Victoria made butters completely free from openness, but the figure for Queensland was 45 per cent. In Victoria crumbliness occurred in 2 per cent. of butters, openness in 35 per cent.

(*f*) *Cheese Starter Studies.*—The initial purpose of the cheese starter studies is to provide a central stock of cheese starter cultures maintained at a high level of activity and of known bacteriophage relationships, so that these may be drawn upon by State Departments of Agriculture supplying cultures to the cheese factories. To permit rapid testing of their suitability for Australian conditions, direct distribution of a series of cultures brought from England was made to some cheese factories. The cultures, while very satisfactory in most respects, showed some instability. This has led to a reassessment of their ultimate phage relationships, and on the basis of the information obtained it should be possible to set up an effective and reliable series of stock cultures.

The experimental use of the existing culture series has, in Victoria at least, led to a re-awakened appreciation of the rapid, reliable, and high-quality cheese manufacture which is possible with properly controlled single strain cultures. Keen co-operation in these investigations has been given by State Departments of Agriculture, particularly that of Victoria which has also provided accommodation for the work at the School of Dairy Technology.

Other fundamental and applied studies related to cheese starter cultures have been undertaken. They include a study of the critical time and dose of bacteriophage attack on starters in the cheese vat; tests of the survival and activity of freeze-dried cultures, and use of this method to preserve and distribute cultures; isolation of bacteriophage strains; studies on phage adaptation, the development of blended or multiple strain starters, and a phage inhibitory medium.

(*g*) *Refractive Index of Sweetened Condensed Milk.*—In the manufacture of sweetened condensed milk a critical point in the process is the determination of the end-point of the concentration. The specific gravity method commonly used has disadvantages, and determination of refractive index is used in some parts of the world. Before the method could be used here, data on the total solids-refractive index relationship for high solids, high fat condensed milk made in Australia must be obtained, and laboratory observations to this end have been made throughout the year.

(*h*) *Other Investigations.*—The effectiveness of various plastic wrapping materials in preventing transfer of flavour from blue-vein cheese to other foods during interstate shipment was determined in a series of simple tests. Volumetric methods of fat estimation other than the Babcock and Gerber method, using less corrosive reagents and not requiring centrifuging, were examined. Further tests were made on the New Way buttermaking process in an endeavour to remedy some texture defects in the butter.

XIII. FOREST PRODUCTS.

1. General.

Work directed to the most effective utilization of forest resources is carried out mainly by the Division of Forest Products, which collaborates with Commonwealth and State forestry authorities and with similar laboratories in other countries; the Division's work is outlined in this Chapter.

Work in the Division of Entomology on timber pests is described in Chapter IX.

Although the operating level of the timber industry varied greatly during the year, requests for assistance were just as heavy as last year. Following a marked recession in the demand for plywood, the officer in charge of the Veneer and Gluing Section visited North Queensland at the request of the Australian Plywood Board to study manufacturing problems there and discuss developments and techniques which could improve products and help overcome buyer resistance.

About 7,000 inquiries were received. Visitors exceeded 1,500, including 88 Army apprentices, 21 teachers, 39 foresters and forestry students, 102 technical school students, representatives from industry, and visitors from overseas. During the year the two Thailand foresters studying veneer and gluing and the Philippine Unesco Fellow studying wood structure, returned to their respective countries. Mr. K. Kumarasamy of the Malayan Forest Service returned home recently after spending nearly a year in the Division studying the operation of a veneer and gluing laboratory and associated activities.

The usual ten-day course in forest products was given to the fourth-year students of the Australian Forestry School, Canberra, and the courses for forestry and architectural students of Melbourne University and for building science students at Melbourne Technical College were continued. An innovation was a special course of a week for third-year students of the Victorian Forestry School, Creswick. In addition to lectures, practical work was given in veneer cutting and seasoning and in plywood manufacture. As logs were selected and cut by the students themselves from the School plantations, there was an excellent demonstration of the effect of silvicultural practices on the quality of veneer. An interesting series of lectures was one for valuers of the Commonwealth Bank, eleven of whom visited the Division for six half-day sessions. Outside lectures and talks were given to oil and paint chemists, sawmillers, foresters, clubs, and some 500 high school boys. In these activities the Divisional film *Science and Wood* was found of great value.

Display material was provided for the Building Research Liaison Service, technical schools, and the "Save the Forests" campaign.

The Division was again well represented at the Sixth General Conference of the Australian Pulp and Paper Industry Technical Association, which was held in Melbourne. The Officer-in-charge, Wood Chemistry Section, Dr. W. E. Cohen, gave the presidential address at the completion of his term of office. The Eastern States Timber Industry Stabilization Conference held in Queensland was attended by two officers of the Division who presented papers and took part in technical discussions.

The F.A.O. Mechanical Wood Technology Subcommittee held a conference at Igls in Austria in August, 1951, and Australia was represented by Mr. R. S. T. Kingston of this Division, who was vice-chairman of the conference. Subjects discussed included stress grading, nomenclature and specifications for building boards, veneers, and plywood. A study group, on which Australia is represented, was formed to consider reduction of waste and improved efficiency in sawing and machining.

The help and co-operation of the paper companies, the Commonwealth Forestry and Timber Bureau, the State Forest Services, the New Guinea Forests Department, and all branches of the timber and allied industries are gratefully acknowledged.

2. Wood Structure.

(*a*) *Anatomical Investigations.*—(i) *Wood.*—Results of examinations of the woods belonging to the Annonaceae and Apocynadeae from the South-West Pacific Area have been accepted for publication. Work has continued on the woods of the Myrtaceae from the same area and the woods of the Cunoniaceae are now being examined. New timber species from North Queensland, New Guinea, and surrounding areas have been examined and the anatomical features of these timbers recorded with the aid of photomicrographs. A survey of the presence of crystalliferous fibres in various timbers has been made, owing to the inaccuracy of available information. To date, fourteen species of ten genera have been found to contain crystals of calcium oxalate in septate fibres.

(ii) *Bark.*—The structure of the bark within the different groups of the genus *Eucalyptus* has been examined. The use of bark characteristics in elucidating problems of classification is under investigation.

(*b*) *Identification and Identification Methods.*—Over 1,100 timber specimens have been identified during the year, including large numbers of specimens from New Guinea, Malaya, Borneo, and the Northern Territory. Many of these identifications have been used to assist botanical determinations for workers in the field. Working from material in the greatly expanded wood collection of the Division and from published information, it has been possible to revise completely the card-sorting key originally developed to place timbers in their correct families or family groups. Since its preparation, this revised key has been carefully checked in the course of many identifications where final botanical determinations had been made and it has proved of considerable value in the classification of an unknown timber. Its use has meant much speadier identification and greatly assisted the classification of New Guinea and Island timbers. The card-sorting keys for Australian and New Guinea timbers, based on macroscopic features only, continue to prove of value, 48 sets of the Australian key and five sets of the New Guinea key having been distributed. The revision of identification methods for eucalypt timbers is proceeding, but preliminary information is being provided in a series of articles in the Division's *Newsletter* to meet demands for help.

(*c*) *Cell Wall and Fibre Studies.*—(i) *Cell Wall Organization and Growth.*—Conclusive evidence has been obtained that extension growth in fibres of *Phormium tenax* takes place simultaneously with the development of the outer layer of the secondary wall. Development of the inner layer follows after cessation of cell extension. However, the formation of the outer layer always occurs behind the region of extension. This indicates a directed synthesis of the cellulose, as previously suggested for the cytoplasm in extending cells, at least in the outer layer. In isolated fibres the tips could be seen with only primary wall present.

In conifer tracheids it is probable that, at most, very slight extension occurs during secondary thickening. However, the structure of the tips was similar to that of the flax fibres in which extension growth is known to occur. The secondary wall was observed to be penetrated by a minute canal so that at all stages of development the cytoplasm would be in contact with the primary wall. Further, it has been observed that in mature cells thickening is often less at the tips than near the middle of the cell, which is suggestive of progressive cell-wall thickening. It has also been shown for several stems that the average cell length increases slightly during deposition of the secondary wall. The evidence obtained suggests that secondary thickening proceeds towards the tips of conifer tracheids and that there is some cell extension at the tips before and during such thickening. These investigations are also of interest in relation to possible causes of spiral growth in conifer stems.

(ii) *Low-angle Scattering of X-rays by Conifer Tracheids.*—Equatorial streaks arising from the middle layer of the secondary wall can be recognized in the low-angle scattering diagram. Meridional streaks are also observed and these, it is considered, arise from the outer layer. From the comparison of low-angle and corresponding wide-angle diagrams confirmation has been obtained of the change in micellar orientation with increasing cell length for all layers of the cell wall.

(iii) *Variation in Cell Length.*—The last Annual Report referred to the correlation between cell length and wood properties and to the possibility of developing from a selected species strains with high initial average cell length. In the continuation of this project, which is being carried out in co-operation with the Commonwealth Forestry and Timber Bureau, some 1,200 different trees of *Pinus radiata* have been examined. From these some 60 have been selected on the basis of tracheid length measurements carried out on the first-formed secondary wood taken several inches behind growing tips. Average tracheid lengths have varied in these selected trees from 1.4 to 1.7 mm., in comparison with the more normal range of 0.85 to 1.3 mm. These trees, therefore, have been used for the supply of cuttings for propagation. When these cuttings have grown sufficiently, check examinations will be made to determine whether the tracheid length of the parent has been carried over into the propagated stock. In the meantime the search for material with high initial cell length is being continued.

(iv) *Examination of Fibres of New Guinea Timbers.*—In relation to pulping studies being carried out by the Wood Chemistry Section on various New Guinea timber species, fibres isolated from available specimens of these species have been examined for average fibre dimensions, the ratio of length to diameter, the ratio of wall thickness to lumen diameter, and the percentage of fibres present in the woody tissue of each species.

(*d*) *Inclusions in Timber.*—Eighteen additional siliceous timbers have been recorded. In co-operation with the Wood Preservation Section certain non-siliceous timbers have been impregnated with silica in small-scale tests. Large specimens similarly impregnated will be exposed to attack by marine organisms. The distribution of saponins in the woods of some families, the use of manganese accumulations as a means of differentiating between certain timbers of the Myrtaceae, and the effect of the calcium carbonate deposits in the vessels of *Sonneratia acida* on the pulp properties of the alkaline-cooked wood have been reported.

3. Wood Chemistry.

(*a*) *Lignin and Related Compounds.*—(i) *Methanol Lignin.*—The existence of at least two fractions in methanol lignin has been confirmed by paper chromatographic resolution in the solvent system, isobutanol: benzene: water (5 : 45 : 50). These two fractions give typical lignin ultraviolet absorption curves, but in view of their R_F values ($R_F = 0$ and R_F *c.* 0.95), it cannot be concluded that either fraction is homogenous. Attempts to resolve methanol lignin in the Craig machine have so far not been successful.

(ii) *Acid-soluble Lignin.*—W. G. Campbell's method (*Nature 169*: 33 (1952)) of recovering acid-soluble lignin from the Klason lignin filtrate has been applied to *Eucalyptus regnans* wood and to partially cooked soda pulp from the same wood. Additional acid-soluble lignin equivalent to 14 and 18 per cent. respectively of the actual lignin contents has thus been recovered.

(*b*) *Wood Carbohydrates.* — (i) *Polyaldouronide associated with Lignin.*—A bulk quantity of water-soluble polyaldouronide has been prepared from methanol-cooked wood, the latter being representative of the twelve outermost growth rings of *E. regnans* and being reproducible at any time in the future. A small quantity of the bulk sample has been fractionated and the fractions hydrolysed and examined by chromatographic methods. The latter have indicated that xylose, galactose, and a uronic acid may be the only sugars or related substances present. Investigation of their derivatives is in hand.

(ii) *Uronic Acids of* E. regnans.—Dilute acid hydrolysis of *E. regnans* wood and neutralization with barium carbonate has yielded barium salts containing 80 per cent. of barium aldobiuronate, the uronic acid content of which represents a recovery of approximately 25 per cent. of that liberated by hydrolysis. A portion of the barium salts has been treated with methanolic hydrochloric acid with the object of obtaining 4-methyl methylglucuronoside methyl ester. The products have been processed to produce a pale yellow syrup which, after treatment with methanolic ammonia and concentration *in vacuo,* yielded a crystalline mass which is now under investigation. An examination of the products of complete methylation of the aldobiuronic acid is also in hand.

(iii) *Holocellulose.*—Chlorine and chlorite holocelluloses contain residual lignin which cannot be removed by further treatment without loss of some carbohydrate material. Sodium hydroxide as weak as 0.2 per cent. concentration, when applied under a nitrogen atmosphere at 20° C., removed a substantial portion of this residual lignin. This lent support to Jayme's theory that alkali-sensitive links may consist of lignin units occurring in the cellulose chain or joining two cellulose chains together. Chlorine holocellulose prepared by the Division's method has a substantially lower degree of polymerization, as indicated by viscosity measurements, than chlorite holocellulose.

(*c*) *Methanol Cooking of* E. regnans *Wood.*—When cooked with methanol in successive stages for a total time of 148 hours at 150° C., *E. regnans* wood lost 75 per cent. of its original lignin (Klason) and 9 per cent. of its original pentosan content. Whereas the lignin was removed progressively, the pentosan was removed during the first four-hour cook.

Except for that extracted during the initial four-hour cook, the lignin extracted at all stages was similar, except possibly for a tendency towards a higher methoxyl content in that which is most readily extracted. There are indications that the wood residues are partially methylated during the methanol cook.

(*d*) *Eucalypt Kinos and Tannins.*—The minor constituents of the zones in cross sections of 23 species (representing eleven families) have been examined chromatographically. In most cases species gave distinct chromatograms which were very similar within each family. In some cases chromatograms of two different families were very similar. Heartwood contained much larger amounts of resolvable components than did sapwood, and with a few exceptions the general composition was the same. The minor constituents of sapwood trees were similar to those from trees containing heartwood but were present in smaller amounts. Bark usually contained the same extractives as did the corresponding wood, but in a few cases this was not so. Chromatograms of the extracts of the leaves and of the root zones of two eucalypt species were found to be similar to those of the rest of the tree. Kinos from four of the eucalypt species contained some components present in the rest of the tree but their general composition was noticeably different. Ellagic acid has been shown to be a common constituent of eucalypt kinos and eudesmin has been isolated from the kino of one eucalypt. Several New Guinea mangrove barks have been shown to be rich in tannin, the exceptions so far being *Camptostemon schulzii* and *Excoecaria* spp.

(*e*) *Pulp and Paper Investigations.*—(i) *The Mechanism of Alkaline Pulping of* E. regnans.—A preliminary study on the removal of lignin and pentosan from the wood and on the yield and permanganate number of the pulp has been made in relation to the following variables: temperature, time, and concentration of pulping reagent. Two pulping reagents have been used, viz. sodium hydroxide and sodium sulphide. The wood sample used was representative of the 12 outermost growth rings of *E.regnans.* It has been found that the slow rate of heating of the steel reaction bombs used in this work renders them unsuitable for obtaining data from which quantitative deductions can be made with regard to reaction rates. The rate of pulping with sodium hydroxide was approximately double for each 20° C. temperature increment between 130° and 170° C. The acceleration of the rate of reaction was found to be less with sodium sulphide than with sodium hydroxide. Increase in concentration of sodium sulphide accelerated the removal of lignin to a greater extent than did increase in concentration of sodium hydroxide, the reverse applying in the case of pentosan removal. At concentrations below 0.25N. lignin was found to be removed more slowly by sodium sulphide than by sodium hydroxide. Comparison of the results obtained with sodium sulphide and sodium hydroxide under otherwise identical conditions has indicated that a pulp of approximately the same chemical composition is reached with each reagent but by a slightly different path.

The effect of chip size on the removal of lignin and pentosan by means of sodium hydroxide and sodium sulphide has also been investigated. Cubes of 1, ½, ¼, and ⅛ in. sides and wood meal milled to pass through 20-, 40-, 60-, and 100-mesh sieves were cooked as in the study just reported, but with sodium hydroxide for 4 hr. and sodium sulphide for 2 hr., both at 150° C. With each reagent there was a fairly steady increase in the rate of pentosan removal as the chip size decreased. The rate of removal of lignin increased greatly down to ¼-in. cube but then remained fairly constant as the chip size was decreased further. This was shown more clearly when sodium sulphide was the pulping reagent.

(ii) *Pulping of New Guinea Woods.*—Pending the collection and receipt of samples representative of stands of New Guinea mangroves, and plantation and virgin stands of the Araucarias growing in New Guinea, some preliminary work has been undertaken on four mangroves and on *Araucaria klinkii.* Of the four mangroves examined three, viz. *Excoecaria* sp., *Sonnerata* sp., *and Comptostemon schulzii,* produced sulphate pulps with satisfactory overall strength properties. The best overall strength was given by the pulp from *Excoecaria* sp., handsheets from which had high tensile and bursting strengths and low bulk. The fourth mangrove, viz. *Bruguiera gymnorrhiza,* gave a sulphate pulp the handsheets from which had low tensile and bursting strengths. The fibres from this mangrove are thick-walled, and on the basis of this preliminary work it has been concluded that this mangrove would be unsuitable as a source of paper pulp produced according to present-day conventional methods. Pulps from the other three mangroves have higher tensile and bursting strengths but lower internal tearing resistance than does standard eucalypt kraft pulp. The three samples of *Araucaria klinkii* which have been examined gave sulphate pulps having good overall strengths, viz. high tensile and bursting strengths and very high internal tearing resistance, all of which compare more than favorably with those of mported kraft pulps. However, this species appears o be very sensitive to variations in pulping conditions, nd its sulphate pulp is more sensitive to beating than s Swedish kraft pulp.

(iii) *Fibre Structure in Relation to Pulp Properties.*—This has been investigated in co-operation with the Wood Structure Section. By taking wood from successive growth rings from a twelve-year-old tree of *Pinus radiata,* material was obtained in which the micellar spiral angle decreased and the tracheid length increased respectively from pith to bark, but in which the basic density varied in a random manner. The wood from each growth ring was pulped to a given permanganate number by the sulphate process by varying the time only, as determined by preliminary cooks, other conditions being maintained constant. The pulps thus produced had similar chemical but different morphological characteristics, and thus afforded an opportunity of relating morphological characteristics to pulp properties. Although tensile strength, bursting strength, and folding endurance all showed definite trends from pith to bark, only tensile strength could be significantly correlated with tracheid length. There was no direct relationship between internal tearing resistance and either tracheid length or micellar spiral angle. In general there were good correlations between basic density of the wood and most of the properties of handsheets made from the unbeaten pulps. Factors which govern basic density, such as cell-wall thickness, have a much greater influence on paper properties than do tracheid length or micellar spiral angle.

(iv) *Application of Urea-formaldehyde Resins for the Development of Wet Strength.*—Two cationic urea-formaldehyde resins of different manufacture have given satisfactory wet strength development when applied to bleached and unbleached eucalypt kraft pulps. These resins enhanced the wet tearing resistance to a greater degree than they enhanced bursting and tensile strengths. In addition, whereas one resin produced the highest wet: dry ratios of bursting strength and tearing resistance, the other produced the highest ratio of tensile strength.

(v) *Influence of Electrolytes on Pulp and Paper Properties.*—A comparison of the effects of distilled water, de-ionized water, and water treated with "Biodemineralit FF resin" on the properties of pulp and paper has indicated that there was little difference between the effects of the three treated waters and that, for the purpose of normal pulp evaluation, there is no advantage to be gained by resin treatment of the distilled water. Several beater addition agents and one preservative, viz. "Belloid TD", "Belloid N.W.", "Sequestrol", and formaldehyde, when added to pulp evaluation-process water, had a negligible effect on pulp properties. Analysis of the ash of papers made in the presence of electrolytes has shown that, whereas anions are not retained by the pulp, cations, especially those of high valence, are strongly retained.

(vi) *Pulping of South-American-grown* Eucalyptus saligna.—Sulphate pulps prepared from 4-, 6-, and 8-year-old trees of South-American-grown *E. salinga* compared very favorably in general strength properties with standard eucalypt kraft, the unbeaten and lightly beaten pulps showing higher strengths than does a commercial eucalypt kraft under similar conditions.

(vii) *Beater Studies.*—When the bronze tackle of the 1.5-lb. Valley Niagara beater was being replaced with stainless steel tackle, consideration was given to the procedure for grinding and assembling the tackle. A new procedure, which it is considered has many advantages over others currently used in Australia and overseas, was developed. The most important advantages of this procedure are that the beater tackle may be taken out at any time for inspection and adjusted and re-assembled without difficulty and that the degree of scouring which occurs during the grinding process can be controlled.

It has been found that it is essential to have the flybar edges slightly rounded if excessive cutting of fibres during the beating is to be avoided. A slight radius on the bedplate bar edges, while not noticeably affecting the degree of cutting of the fibres, definitely enhances the development of internal tearing resistance in long-fibred pulps. Various Lampen mill and Niagara beater comparisons have been made. The installation of the Aylesford beater is complete but work on it has been deferred pending availability of staff.

(viii) *Comparison of Tear Tester Sectors.*—Four sectors, viz., g.cm./17.2, g.cm./68.8, g.cm./137.6, and g.cm./275.2, have been compared on papers ranging in basis weight from 20 to 120 g./sq.m. with the object of determining within which basis weight range the various sectors should be used to give comparable results.

(ix) *M.I.T. Folding Endurance Tester.*—Considerable attention has been given to this instrument, mainly with the object of locating the cause or causes of high variance in folding endurance results, in particular the high first reading which is always observed when papers having a folding endurance of 1500 or greater are tested, and the general tapering off of individual results as testing proceeds throughout the day.

It has been established that the main cause of this variance is the direct-coupled drive with worm and worm-wheel speed reduction. With a v-belt drive and speed reduction pulleys, the average of a series of tests is of the same order as the first reading, instead of being approximately half of it. Furthermore, the individual results vary in a random fashion and do not taper off as testing proceeds. A plastic pinion for engaging the reciprocating rack is also useful. With very steady atmospheric conditions, coefficients of variation as low as 14 per cent. have been obtained.

(x) *Rheological Properties of Pulp Suspensions.*—In the measurement of viscosity and other properties of pulp suspensions in water, difficulties arise from mechanical instability of the system. Other dispersive media of density close to that of pulp fibres have been successfully used to achieve stability so that the suspensions may be subjected to laminar flow to measure viscosity. A Stormer rotational viscometer is being adapted for this purpose.

4. TIMBER PHYSICS.

(*a*) *Physical Properties of Wood and Related Materials.*—(i) *Shrinkage and Density Measurements.*—The measurement of shrinkage and density of Australian, New Guinea, and Pacific Island species has been continued, and work on a number of other species commenced. A detailed study has been made of the variation in shrinkage throughout a tree of mountain ash (*Eucalyptus regnans*). The moisture content-shrinkage relationship has been determined for a softboard of Australian manufacture, the effect of repeated cycles of moisture content variation studied, and the incidence of hysteresis and the effect of previous treatment assessed.

An examination of the standard methods for the determination of linear and volumetric shrinkage has been continued and an attempt made to relate the values obtained.

The variation in longitudinal shrinkage with moisture content has been studied for both early and late wood. The relationship was found to be non-linear, with a maximum differential shrinkage between 12 per cent. and about 6 per cent. moisture content.

(ii) *Wood-Liquid Relations.*—The apparent density of wood substance in various organic liquids has been studied and appears to depend on the degree of swelling in the liquid but no relation can be found between apparent density of the wood substance and molecular weight of the liquid.

The effect of temperature on the sorption of water vapour in wood has been investigated *in vacuo* during both absorption and desorption.

A study has been made of water absorption in insulating and hardboards under various conditions of immersion.

A theoretical investigation has been made into a departure from the additive relationship usually assumed for the specific heat of cellulosic materials with changing moisture content. This departure became apparent in measurements of thermal properties by the variable state method.

(iii) *Electrical Properties.*—A study has been commenced of the variation of electrical resistivity of myrtle beech with temperature and moisture content. Errors due to polarization of the medium, and temperature and moisture gradients have been investigated and overcome by the use of periodically reversed direct current and the immersion of the specimens in a bath of transformer oil.

Tests have also been carried out to determine the effect of chemical impregnation on the electrical conductivity and dielectric properties of white cheesewood and Douglas fir. These tests are a preliminary to the development of an electrical moisture meter for use with impregnated timber. The results show that conductivity and power factor vary considerably with degree of impregnation, especially at high moisture contents, but that the dielectric constant remains substantially constant.

(*b*) *Creep in Wood.*—Additional green beams were set up to study the effect of shear stresses on creep in beams. The relative amounts of creep over the whole beam and over a central portion in pure bending were compared. These beams have now been unloaded and recovery is being observed.

The tests of dry mountain ash beams under prolonged loading have been continued and extended to include an increased number of replications and beams periodically loaded and unloaded. After tests for some months under load, plastic flow appears to account for an increasingly large proportion of the total creep at constant load, but, unless failure commences, the rate of increase of plastic flow later becomes so small as to cease to be measurable over a period of many months.

A number of dry wooden beams under controlled conditions of temperature and moisture content were subjected to various stresses to study the effect of creep on the elastic modulus of the material in bending. The change observed in the elastic modulus was only of the order of 1 per cent. after 35 days under load, the increase being somewhat greater at the higher stresses than at the lower.

Creep tests in tension and compression under controlled conditions have been commenced. From results so far obtained, moisture content appears to have little influence on creep in tension specimens.

Studies of the dependence of delayed recovery on temperatures up to 200° C., thermo-recovery, and swelling recovery after plastic distortion were carried out. Higher temperature resulted in a considerably increased rate of time-dependent elastic recovery and in slightly decreased residual deformation. Soaking in water was found to increase considerably the recovery at ordinary temperatures.

(*c*) *Battery Separators.*—Life tests were completed on batteries containing separators of radiata pine and jelutong (*Dyera costulata*). It is considered that, as far as can be determined without service trials, radiata pine would be suitable for the manufacture of separators but that jelutong would not.

(*d*) *Electrical Resistance Strain Gauges.*—An improved method of manufacturing plastic-mounted resistance strain gauges has been devised and jigs designed.

Resistance strain gauges have been used for tests on floor joists and bolted and nailed joints in roof trusses. They have also been used in creep tests on timber in shear, tension, and compression.

5. TIMBER MECHANICS.

(*a*) *Studies of Properties and Testing Methods.*—As a contribution towards international standardization, two mechanical tests, one used to determine the compressive strength of timber across the grain and the other to determine the shear strength, have been investigated. These tests are performed differently in Great Britain and North America. In the compression test the variables have been tested at different levels with both green and dry material and using different species. This extensive study is still in progress. In the shear test, testing has been confined to a direct comparison of three test methods (the old British Standard method being included). The United States Forest Products Laboratory suggested a co-operative project in which dry material from two species was supplied from America and matched specimens were tested in both countries, by two procedures at Madison and by three at Melbourne. Testing has been completed and results have been sent to the United States. An analysis of the Australian uncorrected results shows that the previous experience with these tests has been confirmed, that is, the cube specimens give higher test values than the rebated specimens.

To overcome difficulties of the conventional ball indentation test for hardness, an impact test, using a dropping ball technique, has been tried. It has now been shown that the test has the great advantage that the results are fundamentally related to size and density of ball and to height of drop. Thus, within limits, it will not be necessary to standardize these factors, but they can be varied to suit conditions and, in particular, the material under test. The test does not damage the specimen and can be used for thin materials such as plywood.

(*b*) *Species Testing.*—Much testing has been carried out to determine the mechanical properties of various species, most work being done on radiata pine grown in Victoria. Many other species were represented, including tallowwood, messmate stringybark, red, white and brown stringybarks, spotted gum, red gum, red ironbark and manna gum. Three species of mangrove from New Guinea were tested to ascertain their suitability for railway sleeper timbers. Altogether green material from about 120 trees and dry specimens from about 110 trees were tested. Arrangements have been made for a comprehensive selection from several Victorian districts of representative material of all the important species. Selection in this way will be much more economical in this State than selection of one species at a time, but the completion of testing of a species will be delayed. Sampling of karri from Western Australia has been carried out and arrangements have been made for the comprehensive testing of South Australian radiata pine, representative of the future crop of the plantations in that State. Authentic samples of about 90 minor species from Queensland were obtained and tests on small specimens were commenced.

One of the chief uses of the mechanical properties of a structural species is the determination of working stresses for it according to defined grades, or alternatively, the defining of grades for the species which will allow the use of specified stresses. In some places it is the present practice to use standard stresses and to "stress-grade" timber to them. A report prepared in this laboratory and sent to the F.A.O. study group shows that, using the "preferred number" principle, it is possible to set up such a series to give rounded-off values which correspond reasonably in both British and metric units.

(*c*) *Silvicultural Tests.*—The micro-testing technique has been used to obtain a time scale in an investigation into the variation of five trees of alpine ash where the growth of the trees had been studied at the time the material was laid down. In the usual test the variation of strength and density can be related directly only to the distance of the material from bark or pith or, at best, to the annual growth, but correlating with time may be a very useful additional technique for special studies.

The Queensland Forest Service has chosen a number of trees of slash and loblolly pine of elite form to be the parents from which clones for future plantations will be established. In co-operation with the Forest Service and the Wood Structure Section an investigation using the micro-testing technique is being made to find out whether the parent trees have satisfactory properties and whether both properties and form are transmitted from one generation to the next.

(*d*) *Timber Construction.*—A pamphlet on the sizes and spacings of timbers for use in framed buildings was issued in 1941, and has become accepted as authoritative by many municipal and governmental bodies and practising architects and engineers. It is specifically referred to in the Victorian Uniform Building Regulations (1945). Following a survey of post-war building practices throughout the Commonwealth, the pamphlet has been amended and enlarged and a new edition prepared.

In long-time loading tests, simple tension joints with single split-ring connectors or shear plates have been under load for several years. Failures have occurred from time to time but they are now becoming less frequent, and it seems that many of the remaining tests may now be terminated.

Columns of several species have been tested under short-time loads in usual laboratory conditions and corresponding tests have been started with the members standing permanently under load. Mountain ash is being used, erected green and maintained in the green condition throughout the test. Short and medium length columns are being used and the loads are 50, 60, and 70 per cent. of the estimated short-time failing loads. Of the 45 columns erected so far all but two of the fifteen under the heaviest loads have failed, mostly within two or three weeks of being erected. Only four of fifteen under 60 per cent. load have failed, and they carried load for two or three months. None of the columns under 50 per cent. load has failed.

The mechanical properties of more than 200 sheets from 26 brands of imported fibre building board have been examined for the purpose of setting up standards and of comparison with previous tests of similar products of Australian manufacture.

In the design of floors it is commonly assumed that a uniform load is applied to the whole floor but investigations by the Commonwealth Experimental Building Station show that on small areas the applied loads may be considerably in excess of this. As considerable distribution of load from the area of application would be expected, testing has been carried out on a simulated hardwood domestic floor and a theory to fit the experimental results is being developed.

Glued laminated timber construction is now being used to some extent in Australia. An investigation has been started of the possible advantages of using external laminae of relatively strong and stiff species on a core of lighter and weaker material. It is envisaged that in the near future pine from plantations will be available in considerable quantity and it may well be economic, in glued laminated construction, to use that material as a core faced with an indigenous hardwood. In the current study radiata pine and mountain ash are being used.

(*e*) *Growth Stresses in Trees.*—The investigation of the release of longitudinal stress has been extended to other age-groups of mountain ash to obtain a more complete picture of the behaviour throughout a species. Creep in the timber is associated with stress irrespective of its origin and creep recovery on release of stress has been measured in trees of mountain ash of various ages between 11 and 120 years. The thermal expansion of green timber and the effect of heat on the relief of stress are of importance in preheating veneer logs and investigations of them have been begun. In some young mountain ash trees, very markedly bent by abnormal snow loads last year, observation has shown considerable and even complete recovery over the whole bend, but in other trees virtually no recovery has taken place.

6. TIMBER PRESERVATION.

(*a*) *General.*—During the past year it has been difficult to maintain a balance between applied and research work owing to the continually increasing volume of requests for technical advice on wood preservation from Government Departments, industry and the public.

There has been further progress towards the establishment of a wood preservation industry in Australia. The need has been recognized by many timber-using authorities, and officers of the Timber Preservation Section have spent considerable time discussing plant design and the economics of different treatments with engineers of railways, power authorities, and the Postmaster-General's Department, and private individuals interested in custom treatment.

(*b*) *Field Tests.*—Inspection of existing field tests and the treatment and installation of new material have been an important phase of the year's work. These tests are now yielding valuable information on the relative effectiveness of different preservative treatments and are clearly demonstrating the economic desirability of treatment of poles, rail sleepers, fence posts, &c. New tests installed include a group of 100 treated fence posts at Highett, Victoria, and a larger test of 279 posts variously treated at the Department of Agriculture Research Farm, Toolangi, Victoria. These new tests include cold soak treatments in light oil solvent preservatives, a method which should have particular value to the farmer.

New tests planned include a large-scale service test of sleepers in co-operation with the Victorian Railways, and a comparative field test of various old and new preservatives in several localities in Australia and New Guinea.

(*c*) *High-pressure Treatment of Eucalypt Timbers.*—Tests with the new high-pressure pilot cylinder have now demonstrated convincingly that the problem of preservative treatment of the heartwood of eucalypt timbers is capable of practical solution. During the year sleepers and crossarms of several eucalypt timbers have been treated rapidly and without damage at pressures up to 1,000 lb./sq. in. Penetration has been generally satisfactory and, with the design and operation of the cylinder now proved in practical test, it is hoped that commercial treatment plants will be installed in Australia. The Victorian Railways have recently designed a high-pressure commercial plant incorporating the basic features of the Division's pilot cylinder. The cylinder has also been studied by engineers of the South Australian Railways, Commonwealth Railways, Western Australian Railways, and the State Electricity Commission of Victoria.

(*d*) *Non-pressure Treatment of Poles.*—As eucalypt poles can be treated in the sapwood without application of pressure, work has been undertaken at the request of the State Electricity Commission of Victoria to permit an early decision on the method of pole treatment to be adopted pending installation of pressure plant. This work was completed and detailed proposals submitted for full-length open tank treatment of poles. The economics of treatment were also examined and shown to be beyond question.

(*e*) *The Preservative Treatment of Crossarms.*—The survey, in co-operation with the Postmaster-General's Department, to determine the causes of failure of crossarms has now been completed for all States except South Australia and Tasmania. Inspection of many thousands of arms has shown a consistent pattern of failure in which the main causes are end-splitting, decay, and termite attack. As such failure can be greatly retarded by correct treatment with preservative oils, work is now planned to demonstrate the practicability and economics of treatment.

(*f*) *The Toxicity and Permanence of Water-borne Preservatives.*—The object of this investigation is to test comparatively, by laboratory studies, the toxicity and permanence of various water-borne preservatives, including proprietary salts. This information is most necessary to extend the results of field tests and to permit safe approval of preservatives for use under conditions which do not simulate outdoor service in contact with the ground (i.e., use in buildings, mines, water-cooling towers, &c.).

Tests are now well advanced with nineteen different preservatives and the method of assessing resistance to leaching is proving satisfactory. In the current series of tests distilled water is being used for leaching, but in subsequent tests the pH will be varied to cover the range which might be expected in normal service. Analysis of residual preservative in the blocks is being made after leaching and leached blocks will also be tested to determine decay resistance.

(*g*) *Timber Mycology.*—Preliminary work to develop a standard technique for determining decay resistance of different timbers in laboratory test has been almost completed. This work has involved the study of many factors, but has been necessary before commencing tests to establish the comparative durability of timbers. In the first series of comparative tests, now commencing, approximately 30 different timbers will be tested under controlled conditions against a selected range of wood-destroying fungi. Collection of test material has been designed to show the extent to which decay resistance is affected by locality of growth, variation between trees, and position within the tree.

Preliminary investigations are also in progress to determine the relationship between durability and the presence in the wood of materials toxic to fungi. Systematic work is continuing on the collection, taxonomy, and cultural characteristics of wood-destroying fungi from Australia and New Guinea. A technique for photographing, describing, and recording cultural and microscopic characteristics has been developed, and is now being applied as a standard method of characterizing the numerous fungi maintained in the culture collection.

A suitable technique for the production of fruiting bodies of wood-destroying fungi under laboratory conditions is being sought. This is of considerable importance in the identification of the many different fungi cultured from sleepers, poles, house stumps, &c., where no fruiting body is present to permit initial identification.

(*h*) *Timber Borers.*—Work is continuing on the biology and control of *Lyctus* and *Anobium* borers. The promising results obtained by addition of toxic chemicals to the glue used in the manufacture of plywood have been confirmed. All laboratory test panels bonded with glues containing DDT or benzene hexachloride are still completely immune to *Lyctus* attack five years after manufacture. This test has been repeatedly inoculated with *Lyctus* beetles and all other chemicals tested have now failed to a greater or lesser extent.

Considerable time has been devoted to the breeding of *Lyctus* and *Anobium* beetles required for tests. Very satisfactory results are being obtained in the mass breeding of *Lyctus* and the techniques used have been standardized. Studies on oviposition and the development of the egg are in progress with *Lyctus.* Preliminary tests to determine optimum conditions for oviposition with *Anobium* have also been made.

(*i*) *Other Investigations.*—During the year an inspection was made of karri wood-stave pipe in the main Goldfield's Water Supply conduit between Kellerberrin and Kalgoorlie. Protective coating systems developed by the Division are now in test on two sections of pipe and results after two years' exposure are satisfactory. Adoption of the most effective system for the coating of 40 miles of pipe should result from this work.

7. TIMBER SEASONING.

(*a*) *Vapour Drying.*—A study of the drying behaviour of some twenty New South Wales and Queensland rain-forest species was completed. Special attention was given to the influence of temperature and pressure on species tolerance. The timbers fall into four main groups based on suitable drying conditions, namely, (i) 260-340° F. and atmospheric pressure, (ii) 200-240° F. and atmospheric pressure, (iii) 180° F. and a vacuum of 27 inches, and (iv) 150° F. and a vacuum of 25 inches. A general relationship between the drying behaviour of each species and some of the more important physical properties (basic density, collapse, permeability, and shrinkage) was indicated. It was apparent that 1-in.-thick timbers of the more highly permeable species may be dried at temperatures greater than 220° F. in from 3½ to 6 hours, whereas temperature control at 150-180° F. and drying times from 30 to 75 hours are required for 1-in. stock of species of low permeability. "Ash"-type eucalypts were dried from the partly air-dry condition (25 per cent. moisture content) in some 10 per cent. of normal kiln time. The partial drying before preservation treatment of sleeper sizes of difficult species was investigated. From 80 per cent. to 50 per cent. moisture content, the drying time required (7 hours) with mineral turpentine was only some 58 per cent. of that required with perchlorethylene.

(*b*) *Drying Studies.*—Earlier work had indicated that a high vacuum might have a beneficial effect on drying quality independent of temperature effects. With the impervious timbers examined, operation under vacuum gave no significant reduction in degrade, although collapse appeared somewhat less and the drying rate somewhat faster. Greatest influence on the latter factor appears to be a low moisture contents. For an impervious collapse-susceptible species the influence of temperature on quality of product was greater than that of time over the range 100-130° F. The sapwood of "ash" eucalypt poles was dried in creosote under a vacuum from the green condition to about 30 per cent. moisture in 16 hours. Further work on the conventional kiln drying of brown stringybark, messmate stringybark, alpine ash, *Albizzia falcata,* black bean, and parana pine was completed.

(*c*) *Kiln Design and Plant Layout.*—Visits were made to 41 commercial wood-using plants to advise on plant design, kiln construction and maintenance, timber and veneer handling, and kiln operation. Detailed layout plans were prepared for eleven firms in all States. Drawings, specifications, and material lists for veneer and timber kilns, and driers for furni-ure panels, corestock, &c., were prepared; 227 drawings were issued. Designs for McCashney mill waste ourners were prepared for 39 firms in all States.

The study of air velocity, boundary-layer conditions, drying rate, and drying quality continued. Further analyses were made of the influence of plant variables, particularly stock thickness, drying time, and plant size, on the economy of kiln drying. Comparing continuous and intermittent drying it was shown that, for a 1-in. thick softwood, the drying times under three-shift and one-shift operation were of the order of 2 : 5.

(*d*) *Building Materials and Products from Waste Wood.*—Sawdust with 10-20 per cent. of *Xanthorrhoea* resin and varying proportions of paraformaldehyde and hexamine gave only a low-quality hardboard having poor water-absorption properties and a modulus of rupture only some 30 per cent. of that obtainable from cresylic formaldehyde combinations pressed under similar conditions. Marked differences were obtained in the physical properties of boards made from softwood and hardwood sawdusts, and increase in sawdust moisture content to a limiting value of approximately 10 per cent. markedly improved mechanical properties and water resistance.

Coconut fibre-resin combinations for hardboard were investigated. Although considerably inferior to sawdust-resin combinations, the addition of 10 per cent. of a cresol-formaldehyde resin gave firm, reasonably hard and uniform boards. Coir fibre dust was found to be mostly of parenchymatous nature and deficient in tannins. Results with urea and cresol formaldehyde, latex, and several casein-latex combinations were disappointing. Addition of coir fibre gave little improvement. Work on bagasse-resin combinations was concluded.

Particle-length distribution and sieve analyses proved useful criteria in the chipping of waste veneer for low-density board manufacture from high-density raw materials. A composite corestock panel, consisting of loosely packed chipped veneer waste with cross banding and face veneers, was made in one operation. Assistance was given to a proposition for the establishment of a commercial wood waste-resin coreboard plant in Victoria. Casein-sawdust floor tiles submitted were tested under accelerated conditions but were not promising.

(*e*) *Other Investigations.*—An examination of the influence of (i) grain direction, (ii) distance from pith, (iii) material width, and (iv) assembly method on the dimensional stability of glued solid coreboard, prepared from small radiata pine log thinnings, was finished. It was notable that this material showed high longitudinal shrinkage, the average being 0.22 per cent. for a 15 per cent. moisture change. A study of the influence of cross banding in compensating for material and manufacturing imperfections was begun.

Experimental work to determine the cause of severe warping which developed in the frames of tennis racquets, during and after fabrication, was carried out. Although straightness of grain and moisture content of laminations were of importance, major influences affecting stability under adverse conditions were the type of glue used and the type of stringing employed. Best combination tested proved to be a urea-formaldehyde resin glued frame with nylon stringing. The inclusion of one or more fibre laminations in the frame almost doubled the frame splitting resistance at string holes.

At the request of a Victorian housing authority examinations were made of the quality and condition of imported pre-cut house parts of central European origin held in storage and being erected at sites in Victoria. Difficulties were shown to be due to a high proportion of timber containing pith and severe spiral grain, and a wide variation in moisture content. The importance of eliminating such material in future deliveries was stressed.

Further studies on commercial heating methods for sterilizing timber with *Sirex* infestation were carried carried out at the request of quarantine authorities. The most effective method was by steaming in open stacks.

Subjects on which information was sought by industry, the public, and government authorities, but which required only limited work, included wood pipe, drying with furnace gases, the drying of ramie leaves, collapse and reconditioning, the causes of warping in doors, chemical seasoning, sawdust-cement products, wood wool-cement products, the design of conditioning rooms and cabinets, drying schedules, prevention of corrosion in heating coils, equilibrium moisture content, moisture-resistant coatings, "working" in wood, the thermal insulation of treating vats, prevention of "ridging" in floors surfaced with asphalt tiles, the handling of timber and veneer, the design of veneer log vats, and methods of moisture determination.

The correspondence course in kiln operation was continued. Twenty-nine students were enrolled and fourteen completed courses during the year.

8. Veneer and Gluing.

(*a*) *Adhesives.*—(i) *Urea-formaldehyde Resin Glues extended with Wheat Flour.*—Anticipating that the Australian plywood industry would in the near future be using larger quantities of urea-formaldehyde resin adhesives which, for economy reasons, would be extended with wheat flour, a project to determine the effect of flour from different sources on viscosity, working life, and other properties of the glue mix was commenced. Flours from a number of distinct wheat varieties and commercial flours produced in New South Wales and Victoria over the past two seasons are being used.

It has been found that the quality of the protein as well as the total amount is of importance. The viscosity of suspensions of the different samples varied very widely.

In resin and flour mixes two effects of the flour are apparent: firstly, an effect on viscosity similar to that observed in the aqueous suspensions, secondly, a buffering effect increasing the pH of the mix and hence the setting time of the glue.

(ii) *Reaction of Amino Acids and Proteins with Diazonium Compounds.*—A study has been made of the coupling reaction between histidine and tyrosine and diazonium salts, and of incidental reactions such as direct diazotization of the amino acids. The absorption characteristics of the azo-derivatives have been determined, and the manner in which the final products depend on the initial concentrations of reactants elucidated. Studies have been made on the spectra obtained by reacting other amino acids with diazonium compounds and the evidence supports the hypothesis that groups other than the phenolic hydroxyl and the imidazole react significantly with diazonium salts. The derivatives of tryptophane, proline, and arginine have also been studied. The absorption spectra of the following intact proteins and their hydrolysates have been measured: casein, paracasein, α-casein, fibroin, gelatin, and pepsin.

(iii) *Role of the Sulphydryl Group in the Formation of Alkaline Protein Gels.*—Cysteine and cystine have been determined in a series of alkali-treated casein preparations. The indications are that the effect of alkalis is to convert disulphide bonds to single sulphur linkages, and that this is likely to be a more important factor in gelation than exposure of sulphydryl groups and their subsequent oxidation to disulphide bonds under highly alkaline conditions.

(iv) *Casein Fractionation and Gelation.*—Acid casein, its α-fraction, and paracasein have been prepared and their rates of gelation in sodium hydroxide solution compared. The rates of gelation decreased in the following order: acid casein, α-casein, paracasein. The relation to amino acid composition and other factors is receiving attention.

(v) *Storage of Undried Casein.*—An experiment is in progress to determine the feasibility of holding freshly precipitated casein in cold storage for six months or more so that an additional quantity of casein could be made available to plywood manufacturers from dairy produce factories without casein drying plant. Bulk samples of lactic, hydrochloric acid, and rennet casein curd, from which the free water has been expressed, stored at 15° F. and at — 1° F. have shown no significant deterioration in gluing properties after two months.

(*b*) *Veneer and Plywood Manufacture.*—Veneer-peeling and plywood-manufacturing studies were made on a wide range of indigenous and exotic timbers grown in Australia, one species from New Guinea and three from Malaya.

Officers visited plywood plants in four States helping to overcome manufacturing problems and discussing methods for improvement of quality of plywood and the use of urea-formaldehyde glues which are now freely available and of liquid phenolic glues which will be available in the near future.

(*c*) *Immunization of Plywood against* Lyctus *Borer Damage.*—Additional commercially produced plywood was installed to permit observations to be made on the effectiveness of incorporating benzene hexachloride in casein glue, the cost for chemical being approximately 1½d. per 100 square feet of plywood. It was distributed through the plywood at the rate of slightly less than ¼ lb. pr 1,000 square feet of single glue-line. Nine months after manufacture slight attack has been observed in some sheets of control plywood, but no attack is visible in plywood with treated glue. Severe attack continues in control plywood prepared eighteen months ago, but no damage has occurred in plywood containing benzene hexachloride at the heavier concentration of almost 1 lb. per 1,000 square feet of single glue-line.

(*d*) *Standards Association of Australia.*—Assistance has been given to the Standards Association of Australia in revising the Australian standard for plywood for general purposes, in preparing draft standards for synthetic resin and protein glues for plywood, and undertaking work leading towards the preparation of a standard for adhesives for labels for export fruit cases to avoid labels becoming detached or mouldy during shipment to overseas markets.

(*e*) *Other Investigations.*—Following successful use of veneer tubes as substitutes for flowerpots in raising seedlings in tree nurseries, treatment of veneers with preservative chemicals to prolong their life and serviceability has provided some interesting results. Seedlings of *Eucalyptus cladocalyx* and *Cupressus macrocarpa* grown in tubes dipped in copper sulphate have grown much faster than those in untreated tubes, whereas the growth of cypress seedlings in tubes dipped in zinc chloride is depressed.

The many items on which assistance has been provided for Commonwealth and State Government departments and industry include equipment and layout for veneer slicing and plywood manufacturing plants, details concerning veneer cutting and drying, gluing techniques, furniture manufacture, the use of decorative plastic laminates in building and furniture, the lamination of arches, radio masts, sporting goods, and door construction.

9. TIMBER UTILIZATION.

(*a*) *Timber Uses.*—The demand from the timber industry, government and semi-government departments, and from firms and individuals for assistance with timber utilization problems was actively maintained. More than 100 individual commodities were studied and advice on suitable timbers was provided. Notes were supplied on more than 70 timber species.

The availability and uses of *Xanthorrhoea* resin were surveyed. Inquiries regarding the substitution of fibreboard for wooden case shooks were dealt with.

(*b*) *Manufacturing Processes.*—Calls for assistance with plant design increased considerably. Layouts were prepared for twelve saw-mills, two dressing plants, a corestock plant, a joinery works, and a furniture factory. Techniques of sawing plantation-grown pine were investigated, and plans prepared for a group of sawing and associated activities were used by the New South Wales Forestry Commission as the basis for inviting applications to commence operations in southern New South Wales. Suggestions were made regarding the siting of saw-mills and dependent plants in south-eastern South Australia and in the Snowy Mountains. Information was supplied on barking machines, log-handling equipment, carriages, log edgers, gangsaws, frame saws, breaking-down saws, breast benches, friction mechanism and gauges for breast benches, automatic rip saws, resaws, slashers, sorting tables, hoists, sawdust extraction systems, portable saw-mills, mobile log cross-cut saws and portable nailing tools. Assistance was given to an intending manufacturer of wood flour in the planning of his operations.

Advice was given on the manufacture of cases, corestock, distillation products, doors, ice cream spoons, laminated beams, laminated skis, photographic veneers, wire-stitched cases, wood wool and wood yeast; the finishing of flooring, furniture, bench tops and weatherboards; the bleaching, fuming and liming of timbers; the removal of stains caused by wood on bricks, hides and clothing; the ventilation of sub-floors; and the installation of plywood floors and the restoration of deteriorated floors.

(*c*) *Waste Utilization.*—Interest in waste wood utilization was maintained. Data on the general uses of sawdust were revised and released in the *Newsletter* The requirements for sawdust used in sweeping mixtures, in sawdust-cement compositions, and in mixtures with various resins were indicated. Information was supplied on the burning of sawdust in space heaters and in industrial furnaces, on the briquetting of saw dust, on the manufacture of fire-lighters, and on th thermal insulation value of sawdust and shavings. Th literature on the use of sawdust as a mulch and as compost was reviewed and laboratory work initiate to find simple treatments for reducing the nitrogen depleting effect of sawdust added to soils. Sawdusts o radiata pine, mountain ash, jarrah, and karri wer prepared for trial as alternatives to granulated cor in the commercial packing of export grapes. A chea sawdust-starch mixture was developed for blockin holes in case shooks.

Experimental production of fibre building board from waste wood and veneer by pulping methods wa continued. Pulps were prepared from pine an eucalypt chips for comparison with commercial pulp and for study of processing variables. Silvertop as and mountain ash pulped in two types of laborator pulpers were found to contain higher percentage fine particles than commercial pulps, and they tende to drain slowly and to stick to the cauls during h pressing. After some fractionation of the pulps an a smear of linseed oil on the cauls, hardboards attractive appearance were produced with modulus rupture between 6,400 and 8,900 lb./sq. in. Sizing wit paraffin-stearic acid and triethanolamine in percentages up to 3 per cent. did not affect strength, and imparted moisture resistance within the requirements of British standards. Fractionation trials have failed to correlate the percentages of different-sized particles with freeness value. Investigations of pressing fibre in the dry condition have establishd relationships between modulus of rupture and temperature of pressing, but consistent relations between strength and pressures from 600 to 1,400 lb./sq. in. have not been found. Increase of temperature during dry pressing improved the resistance of boards to moisture pick-up, but at 1,400 lb./sq. in. the practical limit appears to be 255° C. Exploratory work on wet pressing failed to produce with kraft paper pulp the water burns that are troublesome with fibreboard pulps produced by attrition grinding.

Residues from the crushing of pineapple submitted for investigation were found to contain less than 20 per cent. of material suitable for forming into boards. The material could be handled with less facility than wood pulp, and the strength and moisture resistance of hardboards made were below those produced from wood pulp.

Information was made available to inquirers on sawdust-cement boards, wood waste binder boards, container boards manufactured from straw, and commercial production of hard fibre building boards.

(*d*) *Sawing*.—Experiments with chain saws and circular saws were continued. Sawing chains of the "scratch" type cut at approximately the same rate when woods of low, medium, and high density were fed against the saw with uniform thrust, and the power consumed increased with density. The optimum hook of the outer raker cutting teeth appeared to be —4°. The duplication of results under apparently identical conditions has been difficult, owing to the influence of set. Punch setting of sawing chains in the condition as received has not proved satisfactory when blocks are advanced against the saw or when the saw is swung through fixed blocks. By re-tempering to allow teeth to be levered, satisfactory uniformity of set has been attained, and the jamming of saws in the cutter bar or in the block eliminated. Various profiles are under test in a range of timbers.

Results from experimental circular sawing show that the cutting accomplished with a standard consumption of energy varied with the feed rate. The differences were maintained consistently over the range of density of messmate stringybark. Comparison of a standard circular saw and a safety saw of the "Wigo" type showed that with the same consumption of energy over three feed rates, the standard removed more wood than the "Wigo", even though the kerf of the latter was the wider.

(*e*) *Standards*.—Collaboration with the Standards Association of Australia was continued. Executive duties were undertaken for the Timber Industry Committee and sectional committees, and an active part played in preparing and reviewing drafts of proposed standards. Following on the work of these committees, an Australian standard was issued for wood windows of double hung and casement types. Standard specifications were advanced to the stage of printing for wooden doors and frames, kitchen fitments, waterproof plywood, and grading rules for north-eastern hardwoods. Approval was given for publishing grading rules for scrubwoods, grading rules for south-eastern hardwoods, and a specification for fibreboard butter containers. Committee work was completed and drafts passed for postal ballot on specifications for ordinary plywood, furniture plywood, synthetic resin adhesives, and protein adhesives. Progress was made in the preparation of draft standards for fresh fruit boxes, field lug boxes, and tilers' ladders. Discussion commenced on grades for rifle furniture and for case flitches. Membership was accepted on committees of a standardization working party set up by F.A.O. to consider standardization of timber nomenclature, dimensions, and grading in the south-east Asian region. Views were exchanged on grades for peeler logs, saw-logs, sawn timber of non-teak species, and sawn timber indigenous to Japan, New Zealand, and Australia.

XIV. BUILDING.

1. General.

The work of the Division of Building Research, which is located at Highett, Victoria, is complemented by work carried out by the Commonwealth Experimental Building Station of the Department of Works and Housing, the work of the Division of Forest Products on the properties of timber (Chapter XIII.), the work of the Division of Soils on building foundations (Chapter II., Section 5), and the work of the Division of Industrial Chemistry on cement and ceramics (Chapter XVII., Section 3). Close contact is maintained with Commonwealth and State Departments, the Standards Association of Australia, and the building industry.

Because of loss of staff resulting from reduced funds, it has been necessary to stop active work on some projects and to reduce it on others. Unfortunately the cuts had to be made in the research programme because the flow of inquiries (2,500 during the year) continued undiminished.

Organized visits to the Division were made by delegates to the Annual Convention of the Royal Australian Institute of Architects, by students of architecture of the Gordon Institute of Technology, Geelong, and by Army building trades apprentices. Courses of lectures were delivered to students of the University of Melbourne and the Melbourne Technical College.

The Division was represented at the international Building Research Congress in London in September, 1951, by the Chief and by the Officer-in-charge of Organic Materials Investigations; the latter read a paper on weathering and durability of building materials in the tropics. Both officers attended a conference on building problems in hot climates and the Chief attended a meeting of the heads of building research organizations in English-speaking countries. In addition to spending some months in Great Britain, the Officer-in-charge of Organic Materials Investigations visited Europe and America to study work on the weathering and durability of materials, development of jointing materials, and flat roof construction. Under the auspices of the Colombo Plan, the Officer-in-charge of Masonry Investigations spent four months in Ceylon investigating the heavy clay industry and advising the Government of Ceylon on the future development of the industry. He also visited the Central Glass and Ceramic Research Institute and numerous brick and tile plants in India.

2. Concrete Investigations.

(*a*) *Foamed Concrete*.—Attention has been centred on foamed concrete made by the entraining process (i.e., by simultaneous mixing and foaming) because this is the one most widely used in Australia and is the simplest process for making concrete of medium density (about 90 lb./cu. ft.). Compared with other processes compressive strengths are low at low densities but good at medium densities. At 90 lb./cu. ft. a change of 1 per cent. in density causes a corresponding change of about 5 per cent. in strength. The compressive strength has been shown to depend on the particle size of the sand used, being 50 per cent. higher when the concrete is made from fine sand than when made from coarse sand, in spite of the need to use more water with the fine sand. Several foaming agents proved equally suitable for producing the required properties.

Foamed concrete of about 90 lb./cu. ft. has been found to have an equilibrium moisture content of about 3 per cent. at 70° F. and 65 per cent. relative humidity. Blocks dried to this moisture content are dimensionally stable under constant atmospheric conditions. Since initial shrinkage, which is much greater in foamed than in dense concrete, is the chief cause of cracking of concrete walls, drying of blocks to the equilibrium moisture content corresponding to the climate in which they will be used offers a means of greatly reducing cracking in foamed concrete masonry walls.

Tests on the pozzolanic activity of fly ash (from black coal), calcined diatomite, burnt clay, tuff, volcanic ash, and rhyolitic agglomerate all gave favorable results. Fly ash which had been dumped in seawater for many months appeared to be as active as fresh fly ash.

(*b*) *Theory of Rupture of Concrete.*—A long-term study of the mechanism of failure of concrete under load is being undertaken. Because of the complex stress systems involved the development of suitable instruments is difficult; the application of electrical resistance strain gauges is showing promise.

It has been found that gauges 1 in. long mounted on the tension face of non-reinforced beams are capable of detecting, long before failure, places where cracking is likely to occur, because of the rapid increase of strain at such places.

(*c*) *Periodic Loading of Reinforced Concrete Beams.*—One of the criticisms that have been made of the ultimate-strength theories for the design of reinforced concrete members is that short-time overloads on the structure may produce some permanent weakness, thus reducing the factor of safety below the assumed figure. Tests on reinforced concrete beams subjected to six cycles of load up to seven-eighths of the ultimate showed that they were no weaker than matched beams loaded directly to failure.

(*d*) *Other Investigations.*—The question whether or not standard test specimens of mortar and concrete should be cured in a saturated lime solution was raised during the drafting of standard methods of test for concrete by a committee of the Standards Association of Australia. A short investigation showed that there was no difference between the compressive strengths of cylinders cured in saturated lime solution and those cured in tap water changed every 28 days.

Analysis of a material formed during the breakdown of a concrete seawall showed that it is a hydrated magnesium silicate with a crystalline pattern very similar to that of a hydrated calcium aluminate. More information is being sought on the structure of the material and attempts are being made to synthesize it.

3. GYPSUM PLASTER AND PLASTER PRODUCTS.

(*a*) *Reinforced Gypsum Plaster.*—Reinforced plaster walls are being increasingly used in the construction of houses; unsightly rust staining has occurred in some instances. It has been found that there is no reduction in strength associated with the stains and that they can be avoided by the addition of lime, with only a slight resultant reduction in strength.

The bond between plaster and steel is being examined. Tests made at two and 24 hours showed that the bond at these ages is low and variable. However, in two specimens nearly a month old the bond approached that obtainable with concrete. These specimens when broken open showed considerable rusting of the steel and this was no doubt responsible for the increased strength.

(*b*) *Vermiculite Plaster.*—Plaster containing expanded vermiculite as an aggregate has been extensively used overseas, especially in the United States, as a lightweight fire-resistant building material. In experiments with Australian materials serious trouble was encountered from efflorescence due to soluble salts formed by the slow decomposition of the vermiculite by the gauging water. X-ray diffraction studies have revealed that the local material, although exfoliated enough to serve as an insulator, has not been heated sufficiently to cause a permanent change in the structure of the crystal lattice. Consequently it easily rehydrates and so probably regains the high base-exchange capacity of the original mineral; this may account for the efflorescence.

(*c*) *Hygroscopicity.*—Because of the possibility that the frequent staining of decorated fibrous plaster walls and ceilings was due to hygroscopicity, this property of set plaster was investigated with and without the addition of salts that may be present as impurities in commercial plaster. It was found that the equilibrium moisture content of plaster is very low, approximately 1.5 per cent. at 90 per cent. relative humidity at temperatures between 70 and 80° F. The addition of hygroscopic salts gave only a small increase (up to about 0.5 per cent.) in the equilibrium moisture content and it is, therefore, unlikely that salts in the plaster are the cause of the staining.

(*d*) *Retarders and Mechanism of Setting.*—A study of the behaviour of retarders has begun in the hope that, besides providing practical data on their use, it may throw some light on the mechanism of setting. This work has shown that, when citric acid is used as retarder, increasing the amount does not always increase the setting time; with one plaster, when a concentration of approximately 0.02 per cent. was exceeded, the setting time decreased.

(*e*) *Crystal Structure of Gypsum and Gypsum Plaster.*—The crystal structure of gypsum is to be redetermined with a high degree of accuracy to provide more basic knowledge on the mechanism of the calcining of gypsum. Attempts are being made to produce single crystals of calcium sulphate hemihydrate (gypsum plaster) suitable for X-ray examination.

4. LIME AND LIME PRODUCTS.

(*a*) *Survey of Australian Lime Resources and Industrial Plants.*—Seven more deposits of limestone and dolomite in Tasmania and Queensland have been examined.

(*b*) *Lime Research.*—(i) *Limestone.*—An investigation of the mode of formation and industrial applications of the Permian limestones in Tasmania is nearing completion.

(ii) *Correction of Unsoundness in Magnesian Limes.*—Investigations into the correction of the unsoundness of magnesian lime have shown that the addition of various salt solutions overcomes the unsoundness and makes the lime suitable for general use and for the manufacture of sand-lime bricks. The consistency, workability, and hygroscopicity of mortars and plasters made from treated magnesian limes are little affected. The chemical and mineralogical changes taking place on the addition of the various salts are being investigated.

(*c*) *Technical Advice to Lime Industry.*—Advice was given on the planning of the Australian Aluminium Production Commission's lime-burning and sorting plant at Bell Bay, Tasmania, and assistance on the burning, hydration, and use of lime was given to private firms.

(*d*) *Sand-lime Bricks.*—Considerable assistance has been given to a sand-lime brick company which recently began operations in Victoria. Laboratory studies on heir bricks have shown them to be of good quality. Assistance has been given also to prospective manufacurers in Western Australia and New South Wales.

An acid treatment (followed by washing) for proucing coloured sand-lime bricks, making use of the atural colour of the sand, has been introduced by ne of the companies. Tests carried out in the Division howed that only a very thin surface layer of the brick s affected, that the acid has no deleterious effect, and hat the colour is stable and does not darken. The process is simple and walls already erected may be reated.

The use of carbide-waste lime as a source of lime for and-lime bricks has been studied in the laboratory by n officer of a private company. The wet slurries produced in the usual method of acetylene manufacture did not give satisfactory results, but experiments with dry carbide-waste limes from a new process look promising.

5. Clays and Clay Products.

(*a*) *Survey of the Heavy Clay Industry of Australia.*—In continuance of the survey of the heavy clay ndustry in Australia, 80 more works and clay deposits n New South Wales and north-western Victoria have been visited and several plants in Western Australia and Tasmania were revisited.

(*b*) *Clay Technology.*—Eight samples of clays from Victoria, three each from New South Wales and Western Australia, two each from Queensland and Tasmania, and one from South Australia have been examined in the pilot plant.

The Wianamatta shale from the Sydney area is being thoroughly investigated. It has been shown that by controlling the firing conditions attractive bricks with a red-brown or orange colour can be obtained. Fine grinding of the shale will produce a clay body sufficiently plastic to extrude, but if cracks develop in bricks formed in this manner they will not heal owing to lack of bond in the green state. Furthermore, such bricks have a high firing shrinkage, which causes further serious cracking if the firing rate is too high. These troubles can be reduced by the addition of a plastic clay and experiments are at present being carried out to determine the minimum amount needed to produce a satisfactory product.

(*c*) *Clay Research.*—(i) *Distribution of Clays.*—More detailed attention has been paid to the geology and stratigraphy of the clay deposits of Australia, in particular those in New South Wales and Tasmania, so that an effiecient system of sampling of the more important deposits can be planned.

(ii) *Constitution, Properties, and Behaviour of Clays.*—An X-ray diffraction unit and two differential thermal analysis units for investigating the constitution, properties, and behaviour of clays have been constructed and used extensively for examining clay materials from New South Wales and Tasmania and for studying the rehydration of burnt clays.

Information obtained from the study in the laboratory of the clays from Dover, Surges Bay, and north and north-eastern Tasmania shows that, although they are from widely separated places and of diverse origin, they are remarkably uniform in their mineral content.

The raw materials used in the structural clay-products industry of the County of Cumberland, New South Wales, are being studied. Seventy-three samples representative of three geological ages and of most of the areas of exploitation have been collected.

A most promising deposit of kaolin from New South Wales has been examined and found to be a low-iron mixture of kaolinite and illite which burns off-white. Its plastic and slip-forming properties make it eminently suitable for pottery and stoneware and it could be used in artificial bonding sands and as a suitable filler for paper, rubber, and other industrial products.

(iii) *Bloated Clays.*—With the completion of a small oil-fired rotary kiln and an oil-fired laboratory furnace, progress has been made in the study of Australian clays suitable for the production of lightweight aggregates.

Tests have been conducted on clays and shales from Victoria, Queensland, and New South Wales. A clay from the Melbourne metropolitan area has proved that it has good bloating properties which have been markedly improved by relatively cheap admixtures. Wianamatta and Hawkesbury shales from New South Wales have also given promising results.

The relation between the ability to bloat and the mineralogical and chemical properties of the clay as well as the phase changes occurring during expansion are being studied.

(iv) *Rehydration of Burnt Clays.*—The investigation of the rehydration of various fired clay minerals (illite, kaolinite, limonite, bauxite, montmorillonite, and vermiculite) is now in an advanced stage.

(*d*) *Technical Advice to Industry.*—Inquiries on the various phases of clay product manufacture continue to be received from all parts of Australia.

Assistance has been given to interests wishing to establish a modern brickworks in New South Wales.

Close contact has been continued with the State Tile Works in New South Wales and continued assistance was given to a Victorian company constructing a new brickworks in which a tunnel kiln is being erected.

6. Caulking Compounds.

Caulking compounds have many applications in structures where it is necessary to prevent movement of water through joints the width of which is likely to vary. The rheological properties, the bonding properties, and the effect of weathering on these are the important factors in their performance.

(*a*) *Fundamental Rheological Studies.*—The study of the relation between the flow properties and the composition of oil-based caulking compounds has continued with direct measurements of the flow properties of thick pastes. A polymerized linseed oil of viscosity 40 P. is being used as a vehicle for dispersions of isometric particles of precipitated calcium carbonate and of asbestos fibres. Flow properties have been measured by an extrusion technique. All dispersions of precipitated calcium carbonate tested have shown almost Newtonian flow properties, but the asbestos-fibre pastes studied have had very high yield values even at low concentrations. It is intended to correlate the flow properties of these pastes with such properties of the dry disperse phase as porosity, surface area, and permeability.

(*b*) *Applied Rheological Studies.*—The study of jointing compounds suitable for use in concrete water channels has continued. Attention is being focused mainly on the provision of flow data upon which the design of continuous extrusion equipment may be based.

7. Concrete Floor Surfaces.

The study of concrete floor surfaces to determine the conditions necessary for concrete floors to be acceptable in domestic construction is almost completed.

(*a*) *Physiological Investigations.*—(i) *Effect of Thermal Properties*—Experiments were made on the effect of different floor surfaces on the temperature of the shod feet of fifteen subjects sitting in a controlled-temperature room. It was found that the material composition of the floor has no significant effect on comfort.

There does not appear to be any physical basis for the popular opinion that concrete floors are uncomfortably cold for shod feet.

(ii) *Effect of Mechanical Properties.* — The differences previously observed between the decelerations of the head of a subject walking barefoot on various types of floor surface were shown statistically to be highly significant. Observations have been extended to several other subjects walking, both barefoot and in leather shoes, on the various floors. The results are being examined.

A survey has been made from published data of the use of concrete floors in the United States of America.

In 1950, 22 per cent. of all single-unit dwellings had concrete slab floors, whereas there were none in 1940. Sixty-two per cent. of the better class custom-built homes described in recent leading American architectural journals have such floors, of which nearly half have some kind of hard finish.

It is apparent that in America concrete floors with or without "resilient" surfaces are not considered too hard for comfort.

(*b*) *Durability of Floor Surfaces.*—Attempts to examine the characteristics of abrasion-testing machines have led to the conclusion that, when materials of widely different composition and characteristics are to be compared, there is no substitute for an actual service test. Although such machines may be useful production control instruments for comparing the quality of successive batches of the same material, they fail when it is desired to compare the wearing qualities of new floor-surfacing materials with those of established ones, because of the great variation in the extent to which different materials clog or blunt the abrasive.

Instances of failure of industrial floors made with special cements have been examined. In each, failure was due to the builder's omitting to take the special precautions necessary to ensure success.

8. Bituminous Roofing Materials.

(*a*) *Field Survey of Flat Roofs.*—This survey has been concluded but preparation of the report has been deferred to allow the inclusion of data on European and American roofing practice and performance. There is now ample confirmation of earlier tentative conclusions that the success of flat roofing depends more on the adequacy of the design and execution of the work in general and of flashings and joints in particular than on the quality of the materials. The standard of execution is much lower in Australia than overseas, especially in comparison with that of the United Kingdom.

"Filled" or stabilized coatings, which are almost universally used overseas for self-finished roofing, materially extend the life of the exposed surface and their more widespread use in Australia would be advantageous. Mastic asphalt is used successfully in European countries and especially in the United Kingdom where its excellent performance seems to be due very largely to the traditional and highly developed craftsmanship of English asphalters. It is of interest to note that the migration of such craftsmen to Australia is at present being encouraged by certain asphalting companies.

(*b*) *Experimental Roof Membranes.*—More experimental roof membranes have been laid over the roofs of various buildings and the performance of existing membranes has been periodically noted. The aluminium foil membranes bonded with bitumen emulsions have shown defective adhesion. Surfacings stuck down with cutback bitumens and finished by welting the laps have been more satisfactory.

(*c*) *Laboratory Studies.*—The twelve-month continuous observation of temperatures on a timber deck bituminous-felt-covered roof system treated with various paint compositions has been concluded and the data are being analysed.

Examination of Australian and American saturated asbestos felts showed that there was little difference in the degree of saturation of the respective felt bases but the types of bitumen used as saturant differed considerably. The bitumens in the Australian felts varied markedly in hardness.

9. Thermal Investigations.

A new mathematical treatment has made practicable the calculation of temperatures inside houses and other buildings exposed to fluctuating external temperatures; this is faster and more accurate than the earlier methods using models and electrical analogues and avoids the need for costly equipment. It marks an important development in the study of buildings in hot climates.

One of the main factors to be taken into account in the computation of temperatures inside buildings is the effect of radiation falling on the exterior surfaces. Certain assumptions which have previously been generally accepted have been shown to be incorrect and experimental work on more accurate methods of studying radiation effects is being undertaken.

10. Architectural Acoustics.

Work on the acoustic behaviour of rooms and halls has been concentrated on the feasibility of using models to pre-determine acoustic behaviour and on ways of relating physical measurements to subjective impressions.

(*a*) *Acoustic Models.*—A quarter-scale model of a rectangular room with hard surfaces has been constructed and its acoustic properties have been found to correspond well with that of the full-scale structure. However, much more work is needed before the model theory can be confirmed. So far efforts have been concentrated on measuring the acoustic properties of the surfaces to be used in the models and matching them with the properties of materials used in actual structures. Nine chambers for use in the transmission-characteristic method of impedance measurements have been constructed and are being used to cover the range from 50 to 3,200 c/s. A standard impedance tube has been built for measurements at normal incidence and a new and powerful method of readily detecting inaccuracies in the operation of such tubes by extrapolating from measured minima to zero distance has been discovered.

(*b*) *Subjective Acoustics.*—The reaction of listeners to a sequence of sounds of the same wave-form but separated by small intervals of time, i.e., artificial echoes, is being investigated. The results obtained agree in general with those of Haas, in Germany, but Australian listeners appear to be rather more stringent in their requirements and will not tolerate as loud an echo as was acceptable in Germany. The work is being extended to multiple echoes and to music.

11. Other Investigations.

(*a*) *Polystyrene Wall Tiles.*—Polystyrene tiles installed three and a half years ago in the kitchens and bathrooms of houses are still giving good service, but where the filled drying oil-resin type of adhesive has been used bond failures have continued and are now extensive on all types of background, including paper-covered gypsum board which had formerly given no trouble. The failure of these adhesives may be due to progressive embrittlement with age. Laboratory ests and limited service experience with a rubber atex adhesive showed it to be far better than the rying oil-resin type.

(*b*) *Bituminous Mortar for Glass Tiles.*—The properties of a bituminous mortar (bitumen emulsion, ortland cement and sand) to be used for setting glass iles have been examined. Bond was poor when the ortar was applied to ordinary brickwork but was reatly improved when the bricks were rendered with 1:4 cement/sand mortar or painted with diluted itumen emulsion. The mode of failure was influenced y variations in the bitumen content, but the stress equired to produce failure was influenced very little ven by large variations.

(*c*) *Efflorescence.*—Several instances of spalling and eavy efflorescence, below the damp-proof course, in lay brick, sand-lime brick, and concrete block walls were investigated. The spalling and efflorescence were imilar in all instances, indicating that the damage was independent of the materials of which the walls were made and was due initially to the absorption f salts from the soil.

(*d*) *Under-floor Ventilation.*—Records of humidity and wall temperature were taken over a period of six weeks in a room of a concrete house that showed mould growth and other signs of dampness, and a test, using titanium chloride fumes as a tracer, for movement of air from the under-floor to the room was conducted. Results indicate that high under-floor humidities in conjunction with low wall temperatures may well be causes of such defects.

XV. WOOL TEXTILES.

1. General.

Research on wool production has for many years been a major activity of the Organization and since the establishment of the Wool Textile Research Laboratories in Melbourne, Sydney, and Geelong an extensive programme of work on wool utilization has been developed. A major objective is to improve the competitive position of wool relative to synthetic fibres. Work is directed to increasing knowledge of the chemical, physical, and mechanical properties of the wool; improved engineering of textile machinery; improved technology in the chain of processes through which the material passes; and modification of the fibre to eliminate, or minimize, the less desirable natural properties.

The Melbourne Laboratory is responsible for chemical and biochemical work (Sections 3, 4 (*a*), 7, 14, and 15), the Geelong Laboratory for technology (Sections 2, 5, 9, 10, and 11), and the Sydney Laboratory for Engineering and Physics (Sections 8 and 12, except for the second paragraph of 12 (*a*), which describes research in progress in the Geelong Laboratory). The Division of Industrial Chemistry has continued to study scouring (Section 4 (*b*)), protein structure (Section 13), and the recovery and utilization of wool wax (Section 6). Wool wax is a source of considerable potential wealth which has not yet been fully exploited.

The Melbourne and Sydney Laboratories have been transferred to permanent quarters located respectively at Royal Parade, Parkville, near the University of Melbourne, and at 338 Blaxland-road, Ryde, New South Wales. Building operations are still in progress at the three Wool Textile Laboratories but work is being carried on with existing resources supplemented by temporary buildings.

Pilot-plant work on solvent degreasing at Maribyrnong has been discontinued and work of this kind will in future be carried on at the Geelong Laboratory.

Absence overseas of several officers has led to a temporary suspension of the work previously reported on dyeing and the action of shrinkproofing reagents.

Appreciation is again recorded of the generous collaboration of the Gordon Institute of Technology; the Institute has continued to make facilities freely available and has provided an intensive two weeks' course in textile processing for those of the Organization's officers for whom this is a new field.

Close contact with industry continues and is reinforced by the issue of the *Circular to Fellmongers* from the Melbourne Laboratory and the *Textile Newsletter* from the Geelong Laboratory.

2. Branding Fluids.

L.B.E. branding fluid is now widely used in Australia. About 100,000 gallons were marketed by local firms during the present season. A large-scale demonstration of the scouring properties was given to representatives of the industry at Geelong. The scoured wool has been commercially processed to woollen fabric which has been dyed in pastel shades without any sign of brand in the final product.

It is also being commercially manufactured in South Africa, New Zealand, and Great Britain, and inquiries concerning its preparation have been received from the United States of America, Italy, Uruguay, and Canada.

Experiments are in progress to improve the formula and a much better resistance to rainfall immediately after branding has been achieved.

3. Fellmongering.

Research has continued on the warm-water digestion process for recovering wool from sheepskin pieces. It has been shown in the laboratory that, following shrinkage of the skin tissues in hot water, digestion is hastened by aeration and by the addition of certain salts.

The methods now available to the fellmonger should enable him to produce satisfactory wool and pelts if adequate control is exercised. It is therefore proposed to devote less attention to the study of fellmongering processes in future. Close contact will be maintained with the industry, however, to assist with the adoption of improved methods, to help overcome problems which may arise, and to ensure that future advances in scientific knowledge applicable to the industry are made available.

4. Scouring.

(*a*) *Industrial Aspects.*—Valuable data relating to scouring have appeared in the scientific literature during the past decade. Aspects of practical interest have been summarized and distributed to the industry. New methods of analysis of scouring liquors have been demonstrated.

(*b*) *Mechanisms of Detergency.*—To obtain fundamental information on the mechanism of detergency, and in particular the scouring of wool, the Physical Chemistry Section of the Division of Industrial Chemistry has made a visual study of the mode of removal of mineral oil from wool fibres. It has been found that the periodic fluctuations in the interfacial tension arising from the transfer of soap-forming substances from the oil to the aqueous phase, play a dominant role in spontaneous emulsification, one of the factors of importance in detergency.

5. Solvent Degreasing.

A large-scale combing and processing test was carried out to compare the jet solvent process with normal scouring. The wool was divided into two equal batches, half being degreased by the solvent process and the remainder scoured with soap and soda ash in the normal manner. Both batches of wool were then carded, combed, and processed to fabric in the normal way. It was found that the solvent-scoured product performed better in carding and combing than the normally scoured wool and gave a better yield of top. The jet process has now been set up at Geelong and will be run shortly as a continuous unit, with lanolin recovery, for demonstration to the trade. Arrangements have been made to process wool for mills who wish to examine the benefits of the method.

A combing trial was also carried out with wool solvent-scoured by the drum process and a better yield of top was again observed.

6. Wool Wax.

(*a*) *Chemistry*.—(i) *Aliphatic Alcohols*.—About one-third of the unsaponifiable part of wool wax is a complex mixture of alcohols of high molecular weight, about which little was known, except the aliphatic nature of the alcohols. The programme of work aimed to resolve this mixture by fractional distillation in a spinning-band column and by chromatography has now advanced sufficiently to show that three classes of alcohol are present and to show the main constituents. Six constituents belonging to the anteiso class of alcohols have been isolated in a pure state. They are new compounds having odd numbers of carbon atoms covering the range 17-27. Four new alcohols belong to the iso class; these have even carbon numbers from 20 to 26. Dihydric alcohols form the third class, and five of these have been isolated, but not completely identified. The first two classes constitute the major portion of the mixture. Normal alcohols have not been found and if present at all their proportion must be small. Among waxes, wool wax is therefore exceptional since, apart from esters of sterols and triterpenes, it is composed of branched alcohols esterified with branched and hydroxylated acids.

An analysis of carnauba wax, originally undertaken to develop methods with which to attack the more complex wool wax, has shown that knowledge of this key wax is far from complete. Normal acids containing from 18 to 30 carbon atoms have been found, with C_{24} predominating. These form only 38 per cent. of the acids, the remainder being hydroxy-acids which have hitherto almost escaped notice. This new information should aid in an understanding of the valuable properties of carnauba wax and should be a guide in attempts to modify waxes indigenous to Australia to improve their qualities.

(ii) *Triterpenes*.—Investigation of the wool wax triterpenes has been continued, attention being given to removal of the side chain without modification of the nucleus. Four carbon atoms were successfully removed. Meanwhile work in Zurich and London, in which the side chain was removed with simultaneous nuclear oxidation, has made clear the main structural features of the molecule. The iodoacetates described in an earlier report have now been examined by X-ray methods and from these results it has been possible to decide which of the three possible structural configurations is correct. From this examination it has also proved possible to elucidate fully the stereochemical configuration of lanosterol. This work has been done in collaboration with the Chemical Physics Section. Attention has also been given to the wool wax acids, which have been successfully hydrogenated to alcohols whose properties are now under examination.

(iii) *Wool Wax Esters*.—Separation of wool wax fractions by physical means has involved selective adsorption upon alumina and charcoal, and fractional crystallization from solvents such as ethanol, acetone, and ethyl acetate. By this means the wax has been resolved into groups of esters differing in physical properties; the chemical examination of the esters is in progress. Further resolution into chemical entities has not been achieved, apart from the isolation of free cholesterol. Hydrolysis of each of the above groups has yielded acids consisting principally of hydroxy-acids, some of which lactonize easily.

(*b*) *Recovery*.—The Physical Chemistry Section of the Division of Industrial Chemistry has applied the ore-dressing process of flotation to the recovery of wool grease from scour liquors. The process has been operated on a small pilot scale and the recovery has varied between 35 and 80 per cent., depending on the initial content of grease. The product contains more soap than the high-grade wax (lanoline) obtained by centrifuging, but this disadvantage is offset by the considerably higher recovery. The utilization of this process is under discussion with representatives of the industry.

7. Carbonizing.

Analysis of samples of wool, burr, and liquors, taken at carbonizing works at various stages of the process, have provided useful information on which to base laboratory investigations. Attempts will be made to improve the uptake of acid by the burr and to minimize the loss of wool protein.

Laboratory studies are also in hand to determine the conditions under which sulphuric acid degrades wool and to identify the products of its action.

8. Wool Drying.

Work initiated last year in collaboration with the Organization's Fleece Analysis Laboratory on the transfer of heat and water through wool has led to improvements in the design of wool driers for laboratory purposes, and also to advances in the mathematical theory of heat transfer between fibres and the air. These investigations have been taken over by the Fleece Analysis Laboratory.

9. Yarn Manufacture.

A study is being made of the mechanism of drafting in worsted processing and equipment has been constructed for accurate measurement and recording of the forces developed. Work is in progress on the effects of frictional properties of yarn, spinning speed, and the physical properties of batching oils.

10. Bleaching.

Experiments on bleaching showed that sodium silicate in the presence of a magnesium compound was the most effective stabilizer for hydrogen peroxide of those examined.

11. Chemical Modification of Wool.

(*a*) *Application of Resins to Wool*.—Work on the resin treatment of wool for reducing shrinkage and increasing wear resistance has continued, and the method using nylon derivatives is now at the pilot-plant stage. The process involves two major steps: (i) application of the resin to the wool from an alcoholic solution, and (ii) hydrolysis of the resin with an aqueous solution of an acid.

Three methods of application are being examined: (i) treatment of knitted goods in a washing machine in which the steeped goods may be centrifuged, (ii) treatment of woven fabric with a padding mangle, and (iii) application from a spray gun. Arrangements have been made with a firm of hosiery manufacturers for the commercial development of the process.

Other materials of high molecular weight, in particular proteins such as casein and derivatives of wool keratin, have been found to prevent wool fabric from felting when applied in sufficient quantity. They are not as effective as the nylon derivative, more than wice the quantity of protein being necessary to produce the same reduction in shrinkage.

(*b*) *Mothproofing.*—A colony of moths has been stablished to permit the moth resistance of fabrics o be measured and research is in progress with the object of establishing a new method of permanent nothproofing by the introduction of cross-linkages. Assistance has been given to the Woollen and Worsted Manufacturers' Association in connexion with the nothproofing of goods for Army contracts.

12. PHYSICAL PROPERTIES OF FIBRES.

The physical properties of the wool fibre are paricularly complex and a review of existing knowledge has been necessary. This has included the systematization of the mathematical theories of viscoelasticity, since important phenomena, such as creep and relaxaion, are associated with viscous deformation of wool.

The stress-strain relationship is controlled by three ndependent variables: time, temperature, and the humidity of the surrounding atmosphere.

Investigations now in progress include the relationship of elastic properties to processing behaviour and "handle"; the interaction between wool and water and its effect on mechanical behaviour; and elastic behaviour under loads insufficient to remove crimp—a condition often present during processing and in cloth.

An officer is working in the Chemistry Department of the New South Wales University of Technology on the supercontraction of wool and these studies are expected to provide useful information on the molecular and macrostructure. Interesting facts, which may have practical value in processing, have already been discovered about the inhibition of supercontraction by detergents.

13. PROTEIN STRUCTURE.

The study of protein structure has been continued by the Chemical Physics Section of the Division of Industrial Chemistry. The objectives of the work on proteins are: (i) to increase knowledge of the structure of protein molecules, particularly those of the fibrous proteins such as the wool protein, keratin; (ii) to elucidate the mechanism by which fibrous protein systems are formed *in vivo*; (iii) to discover the relation between fibrous and crystalline protein systems; and (iv) to correlate characteristic structural features and properties of the proteins.

The problem of the molecular structure of proteins has been tackled primarily by the study of the constituent parts—the α-amino acids and lower peptides—using X-ray crystallographic and infra-red spectroscopic methods. Crystalline peptides were synthesized for this work. Structure analyses of several α-amino acids have been completed and that of the tripeptide, DL-leucylglycylglycine, is progressing satisfactorily. The completion of a high power X-ray generator will allow an intensive study of the natural proteins to be made. The way in which the smaller molecular units combine to form structural proteins has been studied for natural and model systems by electron microscopy. The results are consistent with the presence of a linear-aggregation step in the mechanism. Possible methods of polypeptide synthesis are also being studied.

An officer of the Section is spending, by invitation, a period of twelve months at the Textile Research Institute, Princeton, U.S.A., where he is continuing his work on the structure of the wool fibre.

14. PROTEIN CHEMISTRY.

Detailed knowledge of chemical structure is less complete for wool than for the synthetic textile fibres. The problem is much more difficult for a protein fibre such as wool than for the synthetics because, whereas the synthetic fibres are homogeneous in their micro- and molecular structure, wool is heterogeneous. The identity of the amino acids in wool is already known, but the number of types of keratin and other proteins in the fibre, their distribution within the fibre, the configuration of the peptide chains and the distribution of disulphide bonds and other cross-linkages within the fibre proteins, and the arrangement of amino acids within the peptide chains are among the many questions which have yet to be answered. In the course of research to fill these gaps in our knowledge it is expected that valuable data with fairly direct application in the wool textile industry will emerge.

The major lines of investigation are now more clearly defined than they have been previously. They are described below under headings relating to the growth of the wool, the properties of wool keratin and other proteins, methods of protein degradation, and the properties and identity of the degradation products.

(*a*) *Chemistry of Wool Formation.*—Wool synthesis is being studied by laboratory cultivation of the skin tissues of foetal lambs and it is proposed to determine which nutrients are most favorable to the formation of wool keratin. The manner in which energy is made available for wool keratin synthesis will be closely related to the activity of phosphatase and dehydrogenase enzymes in the wool follicle and these are now under investigation by histochemical methods. An explanation has been proposed for the fact that enzyme proteins in general display catalytic properties.

(*b*) *Changes in Protein Structure.*—The stretching of wool fibres and their contraction to the original length or less, as in certain phases of processing and during the wearing of wool fabrics, is believed to be due to changes in the configuration of the peptide chains in the wool molecule. Such changes are termed denaturation and a study of the enzyme protein trypsin has shown that protection against denaturation is afforded by certain metals. Changes in the molecular configuration of trypsin are conveniently reflected as changes in proteolytic activity and the data obtained may be applicable to other proteins, including wool.

(*c*) *Chemical Determination of Protein Structure.*—The terminal amino acids in the peptide chains of proteins which carry the free amino-groups can be identified by the dinitrofluorobenzene method, but no method has been available for identification of amino acids carrying the free carboxyl groups at the opposite ends of the chains (the C terminal groups). Attempts to remedy this deficiency have involved a further investigation into the thiohydantoin procedure which can now be used for the identification of the majority of the amino acids. Although the method is not applicable to the identification of terminal aspartic and glutamic acid residues, it is successful with peptide chains terminating in the corresponding amides, asparagine and glutamine. It has been employed in an investigation of the C terminal end groups in wool.

(*d*) *Production and Properties of Wool Dispersions.*—Various physical and chemical methods of protein and peptide characterization are applicable only to solutions. The conversion of wool protein to a soluble form therefore merits attention and for many purposes this should be accomplished with minimum degradation so that the results will reflect, as far as possible, properties of the intact wool protein. Identification of the products would also serve to identify the bonds split in the process of dispersion.

The possibility of regenerating dispersed keratin in the form of fibres is being explored with a view to developing methods of utilizing low-grade wool or wool waste.

The methods investigated so far involve the use of compounds which reduce the disulphide bonds of wool in combination with protein denaturants or high pH values. For rapid action on the wool, the enzyme papain is also incorporated in the solutions but it is then difficult to arrest the digestion at an early stage.

In the course of examining the physical properties of wool dispersions, measurement of the viscosity of urea-bisulphite extracts has shown the presence of particles having axial ratios varying from 9.9 to 16.3. Estimation of the concentration of sulphydryl groups in a wool fraction by polarographic titration with silver nitrate has given results similar to those obtained by the more conventional chemical method.

In developing the light-scattering method of determining the size and shape of protein particles in solution, experiments have been carried out with dispersions of silk protein. Dispersions of the secretion of the silk glands and also of the fully-formed silk fibre have been used, but increase in the dimensions of the particles during the observations have complicated these experiments. The experience with silk will be of assistance in conducting similar experiments with wool.

(*e*) *Fractionation of Protein Mixtures.*—For some purposes it will be necessary to determine the various components in wool dispersions and to separate them from one another for identification. Electrophoretic methods are eminently suitable for these purposes. The optimum conditions for using paper electrophoresis and moving boundary electrophoresis have been explored by applying them to enzyme mixtures from moulds and higher plants and the techniques are now being extended to the examination of wool fractions.

Fractionation on a larger scale than can be accomplished by electrophoretic methods is effected by precipitation of proteins with ethanol at a low temperature and at low ionic strength. This method is also being applied to the separation of enzymes from mixtures, the homogeneity of fractions separated in this way being examined by electrophoresis.

(*f*) *Wool Damage with Acid and Alkali.*—In addition to the research on the dispersion of wool and other fibrous proteins referred to above, attention is being given to the more extensive degration of wool in acid and alkaline solution, partly to determine the conditions under which damage occurs in mill processes, such as carbonizing and acid dyeing, and partly to contribute further to our knowledge of the chemical structure. Ammonia is one of the first compounds to be released from wool and other proteins when they are heated in acid solution. To help identify the region of the protein structure from which it is released, peptides containing glutamine and asparagine have been prepared and the influence of the mode of combination of other amino acids with these amides on the rate of ammonia liberation is being investigated. The rate of splitting of the peptide bonds between the amides and adjacent amino acids under the same conditions is also being measured, since this may help to explain why aspartic acid is liberated before other amino acids.

A variety of proteins have been prepared in a pure state in order to permit extension of these investigations on synthetic peptides to other proteins in addition to wool.

15. Fungal Degradation of Textiles.

Although many moulds will grow readily on partly-degraded cellulose, very few are capable of initiating the degradation. The former are represented by *Aspergillus oryzae*, and an examination of cultures of this organism by paper chromatography and filter-paper electrophoresis has revealed a multiplicity of enzymes capable of attacking the products of cellulose degradation. These enzymes are termed β-glucosidases, and in addition to hydrolysing the soluble cellulose derivative, carboxymethyl cellulose, they attack several simple glucosides. Collectively they are probably identical with what has been termed the C_x enzyme.

Of the moulds which are capable of initiating the breakdown of cellulose and therefore of producing serious damage in cotton goods, *Stachybotrys atra* has been selected for intensive study. The enzymes from such organisms which attack cellulose directly include what have been described as the C_1 enzymes in addition to the C_x enzymes referred to above.

Techniques suitable for separating enzymes of the above types from one another were developed in an investigation of horse-radish peroxidase. This enzyme also contains multiple components and these are more readily detected and estimated than the glucosidases from moulds.

XVI. PLANT FIBRE.

1. General.

Because of the extension of the activities of the Flax Research Section of C.S.I.R.O. to include work on a number of vegetable fibres in addition to flax, the title has recently been changed to that of Plant Fibre Section. The main investigations, however, are still concerned with processing and spinning flax.

During the year a Commonwealth Fund Junior Fellow from India spent some weeks in the Section for training in methods of cellulose fibre chemistry. Inquiries regarding the training of students in general vegetable fibre technology have also been received from the Philippines under the Aid to South-East Asia plan.

The Officer-in-charge visited Queensland and New Guinea to obtain first-hand knowledge of the work on fibres being done in these areas.

In August a visitors' day was held at the laboratory for representatives of various Government and trade organizations. There have also been numerous other visitors during the year, some from overseas.

The fruitful co-operation between the Section, the Flax Production Committee, and the spinners continues.

2. Agricultural Investigations.

(*a*) *Flax.*—The Section has continued to provide assistance to the Victorian Department of Agriculture and the Waite Agricultural Research Institute in the development of disease-resistant varieties of flax with high fibre content. Samples of some promising strains have been included by the Flax Production Committee in field trials to compare them with the overseas varieties grown commercially in Australia. This work includes spinning performance trials at this Laboratory. One variety, a Norfolk Earl backcross with rust resistance, has given very encouraging results; this year it is to be bulked up for distribution to growers and may well become one of our more important fibre flax varieties.

Fertilizer trials have been planned to study the effect of various nutrients on the fibre development. It is hoped to test theories on plant nutrition deduced from a large number of chemical analyses of leaf samples from growing crops.

Experiments are being made on the cleaning of flax seed and a new type of winnower has been designed which, it is hoped, will provide a more efficient and much simpler machine than is in use at present.

(*b*) *Jute and Jute Substitutes.*—Jute fibre, from field trials by the Queensland Government in 1951, has been tested and the work is being continued. It seems fairly certain that jute fibre, suitable for most purposes, can be produced in irrigated areas in north Queensland, although the cost of production is high.

Jute stems for fibre evaluation have also been forwarded to the laboratory from the C.S.I.R.O. Kimberley Research Station and from the Department of Agriculture of Western Australia.

Material from field trials on the growing of kenaf in Papua and New Guinea and from the Land Research and Regional Survey Section at Katherine is being processed to compare the properties of this fibre with those of jute.

3. PROCESSING.

(*a*) *Water Retting.*—Work has been continued with the aeration of the liquor during the water retting of flax and a modification of the technique has resulted in even faster retting, which is now being completed in considerably less than half the time required by the normal anaerobic method, with frequent improvement in fibre grade. The extension of this method to commercial-scale tests is held up pending the arrival of suitable aeration equipment from overseas.

A difficulty arising from the presence of the weed loose-strife (*Lythrum hyssopifolia*), which appears to inhibit growth of retting bacteria, is being investigated.

Investigations have been made of the retting of jute stems and of ribbons obtained from the green stems by feeding them through a stripping machine. The ribbons are then dried and retted. The advantages include quicker retting and reduced bulk to be handled, but there is the disadvantage that sufficient machines must be available to treat the whole crop at the time of harvesting. The retting investigations have included the effect of temperature, the ratio of jute to retting water, and the inoculation of the ret with liquor from flax rets.

Bacteriological and chemical studies of the ret as an environment for the retting organisms have continued.

(*b*) *Drying Retted Material.*—Artificial drying is very expensive and has not been widely used in Australia. The alternative that has been adopted is to discontinue retting during wet weather, but this is not always possible. In a series of tests recently concluded the retted straw was spread mechanically on the ground in a thin layer instead of being "gaited" in sheaves. After drying, the straw was gathered by means of a pick-up binder. The scattering of the straw by high winds proved a serious drawback. The use of specially designed drying racks is also under consideration.

(*c*) *Scutching and Mechanical Decortication.*—At the request of the Flax Production Committee a detailed survey has been made of the scutching operation and the staff problems it involves in Victoria flax mills. Recommendations have been made regarding such factors as the optimum number of feeders, the best method of taking-off, and the chief points of maintenance. However, because of the variability of the raw material, a certain elasticity must always be present and arbitrary regulations will never replace good management.

Studies of the performance of the flax scutching machine itself have further demonstrated amongst other things the advantages to be obtained from the use of a variable-speed drive rather than the present three-speed gear-box. This is particularly so in hot, dry weather when heavy fibre losses will occur unless the beating speed is carefully controlled. It was also found that operations under very dry conditions can be further assisted by injecting steam into the scutching drums.

Some preliminary experiments have been made on the mechanical separation of the fibre from the stalks of retted jute and kenaf by drying, breaking, and scutching. The results have been encouraging.

(*d*) *Preparing and Spinning.*—Studies of modifications in the preparing and spinning technique and their effect on the strength and regularity of the yarn produced have enabled the Laboratory to build up a background of information on the manufacture of flax yarn. During the year assistance was provided to a firm of local flax spinners in assessing the advantages of proposed changes to their preparing and gill spinning system.

(*e*) *Boiling and Bleaching.*—In addition to routine boiling tests on the yarn from most flag spinning trials, a careful study is being made of the more fundamental aspects of the process. An experimental kier with a capacity of 1 lb. of yarn is now in operation. The work has included a study of the role of wetting agents in boiling and methods of determining the progress of the "boil" from the properties of the boiling liquor.

4. UTILIZATION OF WASTE MATERIALS.

Considerable progress has been made in developing economical methods of utilizing short flax crops. In the past, such crops as would not produce straw at least 24 inches long when cut have been rejected by the flax mills and the grower has suffered considerable loss. Lodged crops which could not be harvested in the form of sheaves have also been rejected. Last season two selected short crops and one lodged crop were purchased by the Flax Production Committee. They were processed into spinners' tow under the direction of the Plant Fibre Section and will return a profit to both the grower and the Committee. Not all "reject" crops will be recoverable in this way; some have so little fibre in them that they could not be processed economically. Nor will there be one hard and fast method for treating these crops; each will have to be considered on its merits both as to its value and the method by which it will be harvested and processed.

Improvements in the method of feeding flax shives to boilers so as to reduce fire risks and at the same time improve the boiler efficiency are being investigated, but only limited progress has so far been made.

5. CHEMICAL INVESTIGATIONS.

Research has been continued on the identification and estimation of the materials in association with the cellulose of flax fibre and the effects of these materials on the spinning quality of the fibre. Water-soluble constituents have been qualitatively determined by chromatographic technique and subsequently analysed quantitatively. A method has been developed for the determination of galactan. Work on the determination of the materials soluble in N/50 sodium hydroxide has been continued and consideration given to the extraction of the fibre with 2 per cent. sodium hydroxide in order to determine more exactly the materials dissolved in a complete alkali boil.

Several kenaf fibre samples have been analysed for wax, water-soluble, and N/50 sodium hydroxide-soluble contents.

6. PHYSICAL PROPERTIES.

(*a*) *Fibre Properties.*—In an investigation of the relationship between stem anatomy and fibre properties a number of statistically significant correlations have been observed. These allow an estimate to be made of the potential quality of the fibre, by the examination of stem sections. Such estimations can be made for small straw lots from which fibre for testing could not be obtained by normal fibre extraction methods.

As part of the work of assessing their commercial value, various physical tests have been made on fibre bundles, too small to be spun into yarns, from a number of samples of kenaf, sisal, roselle, *Urena lobata*, jute, and manila hemp.

(*b*) *Yarn and Cloth Properties.*—The determination of yarn properties, such as uniformity and strength, is complementary to spinning tests and may be regarded more in the nature of routine testing. However, investigations have also been made to compare the results obtained from different types of testing machines as there is as yet no standard method for this purpose and confusion often occurs.

Yarns from kenaf fibre, both retted and decorticated, have been compared with jute in resistance to fungal attack and knot efficiency.

XVII. INDUSTRIAL CHEMISTRY.

1. General.

The Organization's chemical research in undertaken mainly by the Division of Industrial Chemistry, which has its head-quarters at Fishermen's Bend, Victoria. In addition to the work of the Division described in this Chapter, its investigations on wool scouring, wool wax, and protein structure are described in Chapter XV., Sections 4 (*b*), 6, and 13, work on the flotation of minerals in Chapter XVIII., Section 4, and work on the utilization of brown coal in Chapter XIX., Section 7.

Most of the staff is located in Melbourne but twenty officers are located in other parts of Australia. In Perth, officers are working in the Chemistry Department of the University of Western Australia on vacuum ultraviolet spectroscopy, on the chemistry of alunite with a view to its utilization in the production of potash fertilizers, and, in association with the Veterinary Research Institute, on the physiologically active alkaloid in the Dwalganup strain of subterranean clover which is injurious to sheep.

In Adelaide, the Division operates a Ceramics Research Laboratory in conjunction with the South Australian School of Mines and Industries, with the support of the South Australian Government. This laboratory has investigated a wide variety of local raw materials and the technical advisory service which it provides has been freely used by the local ceramic industries. In addition, an officer is working in the Assay Department of the School of Mines and Industries on analytical problems associated with the recovery of uranium from South Australian ores.

At the University of Melbourne accommodation has been available, through the generosity of Professor E. J. Hartung, for the Division's microanalytical laboratory, which has continued to meet a heavy demand from scientific institutions and from industry for microanalytical work.

At the Melbourne Technical College, a Foundry Sands Section provides a testing and technical advisory service to the foundry industry.

In Sydney, a laboratory located in the Department of Chemical Engineering of the University of Sydney is specially equipped for physico-chemical research at high pressures.

In addition to these officers who are directly concerned with the work of the Division, a number of others have been seconded to other parts of the Organization.

On the initiative of the Division, Professor E. A. Guggenheim, F.R.S., Professor of Chemistry, University of Reading, came to Australia and spent approximately half of his four months' visit at the Division. Professor Guggenheim, an acknowledged authority on thermodynamics, has wide interests in theoretical chemistry and was able to make a substantial contribution to many projects. The Organization arranged visits by Professor Guggenheim to all mainland capital cities, where he visited chemical laboratories, discussed research problems with many chemists, and delivered a number of lectures.

About twenty guest workers were accommodated during the year. In some instances this led to fruitful collaboration, in others the object was to provide training in specialized techniques or to give access to equipment and facilities not readily available elsewhere.

Through the generosity of the Pennsylvania State College, United States of America, it has been possible to send an officer of the Chemical Physics Section to this institution for twelve months to work with Professor R. Pepinsky, an authority on automatic computing machines. The extended application of automatic computors will greatly facilitate the analysis of X-ray and electron diffraction data.

The H. G. Smith Memorial Medal for 1951 has been awarded to Dr. A. L. G. Rees, officer in charge of the Chemical Physics Section. The medal is awarded annually to the member of the Royal Australian Chemical Institute who has contributed most to the development of some branch of chemical science. The Institute's Rennie Memorial Medal for 1950 for the best contribution to chemical science development in Australia has been awarded to Mr. D. E. Weiss, of the Physical Chemistry Section.

The Division has played a notable part in devising and evaluating processes for the extraction of uranium from Radium Hill ore. With the decision to undertake production in South Australia the Division's interests in Radium Hill ore have changed from uranium to the rare earth and titanium compounds which are important by-products from this ore. Investigations on the extraction of uranium from Rum Jungle ore will continue, but the rate of progress in the immediate future will be limited by depletion of staff caused by the transfer of several of the Division's officers to the South Australian Department of Mines. They will form the nucleus of the chemical and chemical engineering staff which will operate the plant for treating Radium Hill ore. This transfer of trained staff, though not without adverse effect on the continuity of the Division's programme, is one means by which it can make a valuable contribution to work of national importance.

An important service to industry is provided by making the Division's pilot-plant equipment available for testing processes developed in other laboratories. A description of this equipment has been published and reprints are available on request. Short articles summarizing those of the Division's publications which may be of direct interest to industry have been contributed to technical journals. The receipt of numerous requests for further information indicates that these articles are useful. In addition, some hundreds of inquiries have been answered by officers of the Division.

The following description of the activities of the Division focuses attention on the work of the scientific and technical officers. The essential part played by the clerical and stores staff and by the workshops staff is recorded with appreciation.

2. Minerals Utilization.

The research programme of this Section is based on the development of new methods of processing minerals and the fundamental study of the chemistry of their constituents in order to extend the range of their derivatives and their industrial applications.

(*a*) *Rare Earth Minerals.*—Work on the separation of thorium, cerium, and the cerium group of lanthanons referred to in the 1950-51 Report has continued. Separations based on fractional crystallization, or partial precipitation, of mixtures have been supplemented by processes using ion exchange columns for preferential absorption of organic complexes of the lanthanons, and solubility studies in non-aqueous solvents were also made. Investigations on the chemistry of thorium compounds have been continued particularly with regard to the carbides and iodides which are of importance in the production of the pure metal. Methods of general applicability for the isolation and purification of thorium compounds from crude rare earth mixtures were almost completed and studies on the complex potassium fluorides of thorium were concluded. During the year satisfactory small-scale production of cerium oxide optical polishing powder was reported by one Australian company normally engaged in mineral production from beach sands. The process used was that developed by the Section in its earlier work on the applied chemistry of the lanthanon group.

(*b*) *Zirconium Minerals.*—The eastern Australian beach sand deposits of zircon are among the most extensive in the world. Zircon is a rich ore of the increasingly important metal zirconium and a source of a wide range of non-metallic derivatives relating to industrial refractories, ceramics, &c. Developmental work on the patented process for the separation of zirconium from the closely related element hafnium, reportd in 1950-51, has continued. Satisfactory progress has been made and a notable feature of the preferred method is that both the zirconium and hafnium, when resolved, are in a form which admits of their conversion to the respective metals without further modification.

(*c*) *Titanium Minerals.*—Apart from the problems of processing the titaniferous uranium ores of South Australia, the section has been chiefly concerned with the extensive deposits of high-grade rutile which are such a remarkable feature of the heavy mineral sands of the eastern Australian beaches. Apart from its utilization as such, in electrical welding-rod fluxes, this rutile offers opportunities for the production of many titanium derivatives which are less conveniently or less economically derived from lower-grade minerals such as ilmenite. For some time past a series of products derived from titanium tetrachloride has been under investigation. The study of the properties of titanium nitride has been continued. This material when suitably bonded shows very promising qualities as a hard "metal" in the same sense that tungsten carbide is so described. As in all such products it is necessary to effect a compromise between the two related qualities of hardness and brittleness. To this end it has been necessary to study many inter-related factors, such as appropriate bonding metals, compacting pressures, heat treatment, &c. Recent results from this work suggest that a useful industrial product may be devised.

(*d*) *Manganese Minerals and Graphite.*—Manganese oxide and graphite are both required for electrical dry-cell manufacture and, although both minerals occur in Australia, it was previously considered necessary to use imported materials. Work was first directed to elucidating the obscure factors which determine whether any particular manganese oxide is suitable for use as a depolarizer. It was necessary to investigate both fundamental and applied aspects of dry-cell chemistry, and the knowledge gained has been of use to Australian manufacturers who have collaborated throughout. It has been shown that traditional objections to certain impurities in the minerals are unfouned, and means for the removal of deleterious impurities have been devised. The investigation has shown quite clearly that certain Australian minerals are in no way inferior to accepted overseas materials. The original objectives of the project have now been achieved but work is being continued on certain fundamental aspects likely to be of importance in other fields.

X-ray diffraction studies relating crystal structure of various manganese oxides with their chemical reactivity have been extended to analyses, now completed, of the crystal structures of the manganese minerals cryptomelane, lithiophorite, and psilomelane; an analysis of the structure of chalcophanite is proceeding. Apart from the studies of the behaviour of South Australian graphite in electrical dry cells referred to above, work has been continued on the lamellar complexes which, under certain conditions, graphite form with some metallic chlorides and related salts. The number of such compounds has been notably increased in the current period and attention has been given to the possibility of their industrial use in the selective separation of the vapours of certain mixed metallic chlorides.

(*e*) *Uranium Ores.*—The chemical processing of two Australian uranium ores has been investigated. In each case the object of the work has been to devise a method for the chemical extraction and isolation of the uranium as a salt or oxide from either mineral concentrates or crude ore. The titaniferous iron ore, containing davidite, from Radium Hill, South Australia, has been processed with good recovery values by leaching with acids and solvent extraction. The process, which was taken to pilot-plant stage, allowed the recovery of certain by-products as well as uranium.

Attention is now concentrated on methods for processing a different class of uranium ore from Rum Jungle, in the Northern Territory. Laboratory-scale tests indicate that this ore is likely to prove amenable to the treatment devised without prior mechanical concentration and may be expected to yield high recoveries of its useful components.

3. CEMENT AND CERAMICS.

The programme covers a wide range of investigations on problems connected with portland cement and general ceramics; it includes investigations on pozzolanic cements and on various types of refractories, and a survey of Australia's resources of ceramic clays.

The Section has received both practical and financial assistance from the Cement and Concrete Association of Australia and from the National Gas Association of Australia.

(*a*) *Cement-aggregate Reaction.*—Further papers have been published on the general mechanism of this type of reaction, which sometimes occurs between cement and certain types of sand or stone used as aggregate in concrete. It can lead to expansion, cracking, and subsequent deterioration in concrete structures. Most of the laboratory observations which have previously been made on this problem have been based on the behaviour of mortar bars containing high-alkali cement and reactive aggregate of fine grain-size. Such mixes with the addition of coarse aggregate are now being studied in order to obtain a more accurate prediction of the behaviour of concretes used in normal constructional practice from the results obtained in a standard testing procedure. Attention is being given to methods for restoring concrete which has cracked and for the prevention of further damage by subsequent weathering. The rate of movement of alkalis in cement pastes has also been the subject of a laboratory investigation which has shown that potassium tends to diffuse more rapidly than sodium. The actual rates at which potassium and sodium hydroxides react with silica are, however, very similar, and, in order to gain further knowledge of this reaction a comparison has been made with the behaviour of lithium hydroxide, which itself reacts more slowly and is known also to have an inhibiting effect on the reactions of the other alkali hydroxides. A radio-active tracer technique is also being used to study the reactivity of different types of silica. Arising from this general investigation is a study of the mechanism of expansion cracking in cement paste, mortar, and concrete. Apparatus is also being developed for a study of shrinkage cracking.

(*b*) *Pozzolanas.*—These are materials which, either in the natural condition or after heat treatment, possess cementitious properties when finely ground and mixed with lime. They are sometimes used to improve the durability of concrete and to give increased resistance to reaction between cement and aggregate. A description of methods which have been developed for evaluating them is now in the press. The study of the properties of a variety of pozzolanic materials, mostly of Australian origin, has been continued, with particular reference to mortars made from lime and pozzolana and from portland cement-pozzolana blends.

(*c*) *Surface-active Agents in Cement and Concrete.*—The durability of concrete may be improved by the use of surface-active agents to promote air entrainment. Current studies include the effect of soluble materials derived from hydrating cement on the effectiveness of various agents and the relationship between sedimentation behaviour and entraining effectiveness.

(*d*) *Mineralogical Investigations.*—Phase equilibria of silicate systems at high temperatures are being investigated in order to elucidate the occurrence of sodium in cement clinker and of zinc in lead blast-furnace slags. A similar study of basic steel slags has been completed. Equilibrium relationships of certain thorium compounds have been determined in collaboration with the Minerals Utilization Section; an account of this work is now in the press. Mineralogical investigations have also been made on aluminous and chrome-magnesite refractories which have been attacked by alkalis, on the structure of pozzolanic mortars, on slags, and on concrete aggregates.

(*e*) *Cement-kiln Refractories.*—Bricks of stabilized cement clinkers have been made and burned successfully, and the properties of these refractories are being examined. Work on the production of high-alumina refractories from Australian materials has been begun. The study of factors affecting the durability of kiln linings has been continued. Chrome-magnesite and sillimanite bricks attacked by alkalis derived from the raw materials of cement have been examined and the nature of the deterioration has been revealed. Changes in the cross-sectional dimensions of a cement-kiln caused by heating and rotation are being measured in order to study the stress conditions in the lining.

(*f*) *Gas-works Refractories.*—A critical study of the physical properties of refractories used in gas retorts in Australia has been published. An investigation of the factors limiting the durability of gas-works refractories under conditions of heavy steaming has continued. A retort so affected has been dismantled and photographed and appropriate specimens collected. Work continues on simulating in the laboratory the conditions in an operating retort.

(*g*) *Clay Resources Survey.*—An extensive account of the ceramic and refractory clays of South Australia has been published. A similar study of Western Australian clays has continued and the laboratory investigations are nearly complete. The examination of samples from Queensland has begun. These samples are being acquired through the collaboration of the Queensland Geological Survey. A critical examination of the methods used to determine the modulus of rupture, base-exchange capacity, and dye-adsorption index of clays in this survey has improved the reliability of the values obtained. A thorough examination of the factors involved in dye adsorption may provide a rapid and simple technique for assessing the specific area and activity of clay surfaces, which are of great importance not only in ceramics, but in most industrial applications of clays.

(*h*) *Clay Mineralogy.*—The recent completion of X-ray diffraction equipment has permitted a start to be made on the characterization of indigenous clays according to their mineral content. X-ray techniques are also being applied to a study of the configurations taken up by water molecules associated with the active surfaces of clay minerals. Work of this kind is aimed at increasing fundamental knowledge of the properties of clay-water systems, and has ultimate application in fields such as agriculture, construction engineering, and oil-well drilling as well as ceramics. Direct evidence of the surface-water relationships is difficult to obtain because of the very small grain-size of the clays. A new approach has been initiated by a structural study of vermiculite, a mineral unique in that it forms in clays and also occurs elsewhere as flakes large enough to be investigated by single-crystal X-ray techniques. It is closely related structurally to the important clay mineral montmorillonite and, like the latter, consists of complex aluminosilicate layers interleaved with layers of water molecules and carrying exchangeable ions. Evidence of precise orientation of the water molecules and exchangeable ions with respect to the silicate surfaces has been obtained.

(*i*) *Silica Investigations.*—Microcrystalline silica (flint) is an important constituent of certain English whiteware and has some advantage over quartz, particularly in producing a body resistant to crazing. Efforts are being made to locate Australian sources of supply. A study, more detailed than any previous ones, of the physical properties of both raw and calcined microcrystalline silica has been published. A study of the physical properties of South African silcrete bricks shows that they are of high quality. Australian quartzites including those of the silcrete type are being examined with the object of producing silica bricks of a similar standard.

(*j*) *Whiteware and Related Investigations.*—Studies of whiteware bodies have revealed new points of interest concerning their porosities and microstructures. The results are being prepared for publication. For the first time a detailed investigation has been made of the deformation of plastic clay in which the orientation of the clay-mineral crystals is known. An account of this work is in the press. Investigation of the fusion of granitic materials used as fluxes has been specially directed to the collection of gases evolved which may cause "bloating" in ceramic bodies.

(*k*) *Saggar Investigations.*—Saggars developed from South Australian and other materials continue to give good service under industrial conditions. An account of the investigation has been published; it deals also with saggars of improved type which do not require a high initial firing temperature.

(*l*) *Special Ceramics.*—Titanate dielectrics have been specially prepared in the Section and are giving satisfactory service in equipment being operated by another government research laboratory.

(*m*) *Adelaide Ceramics Laboratory.*—In addition to investigations into a wide variety of raw materials, physical tests on refractories and other ceramic products have been made. The technical advisory service continues to be in great demand.

4. Foundry Sands.

The activities of the Foundry Sands Section have been concerned with all aspects of the metal moulding industry and not restricted to moulding sands. The Section has provided an advisory service to all branches of the foundry industry, which has involved numerous visits to foundries by members of the Section and the undertaking of laboratory investigations on a wide variety of foundry problems.

A continuous survey of Australian moulding sands and clays has been maintained, samples from newly developed deposits being tested as they have become available. An extensive revision of an earlier survey of Victorian sands has been continued in conjunction with the State Department of Mines.

Investigation of organic binding materials for sand ores and of clays for use in blending synthetic moulding sand mixtures has continued.

5. Physical Chemistry.

(*a*) *Separation of Antibiotics.*—There has long been need for an efficient process analogous to fractional distillation for the separation of the components of certain types of complex mixtures. It has been evident, for example, in the large-scale production of the antibiotics such as penicillin and streptomycin. Attempts have been made to develop a new process based on the fractional adsorption of the active components on solid adsorbents, and applications have been made for patents covering the process. The principle of the method is a countercurrent extraction in which a specially prepared solid on which the antibiotic is adsorbed descends against a rising column of liquid (reflux) which removes the contaminants. A pH gradient in the adsorption columns corresponds to the temperature gradient of a distillation column.

It may be operated continuously or used, like a batch distillation, to produce several products during the one treatment and it is economical of both adsorbent and solvent. Some engineering problems have yet to be solved before the process can be regarded as suitable for industrial use. In the course of this work a new adsorbent was developed which may have a wide use for industrial processes because of its cheapness and reproducibility. The equipment which was developed for the above process is also being used in a new process for the continuous softening of water by ion exchange resins.

(*b*) *Properties of Fluids.*—Work has been continued to obtain accurate data concerning the physical properties of fluids and the manner in which they are influenced by change of temperature and pressure. To obtain such data and develop methods of predicting the behaviour of fluids under a variety of conditions is of considerable importance in practical problems of chemical engineering design. The second virial coefficients of silane, silicon tetrafluoride, and ethylene have been determined with a high degree of precision. These coefficients indicate the magnitude of the departure of certain properties of a gas from those which would be exhibited by a perfect gas.

There is considerable discrepancy between the behaviour of certain light gases, such as hydrogen and helium, at high pressure and that expected on the basis of current theory. A new theory based on the quantization of the motion of these gases has been developed which has enabled their behaviour to be predicted closely.

Certain problems have arisen during the year which have involved the measurement of dielectric losses of methyl fluoride and ethylene above their critical points, and also the variation of electrical conductivity of ammonia solutions with pressure.

Thermodynamic data are also being obtained on pure liquids and binary mixtures. Equilibrium data have been determined experimentally for the systems benzene-*n*-heptane and their vapours, and *n*-hexane-chlorobenzene and their vapours. Precision equipment is being made for determining the heat of mixing of two liquids.

A theory has been developed from which the properties of mixtures containing alcohols can be predicted. Such mixtures are of considerable industrial importance but their complexity has hitherto prevented detailed theoretical treatment.

(*c*) *Heterogeneous Catalysis.*—The adsorbent materials widely used as catalysts in the chemical industries to accelerate chemical reactions are usually fine powders compressed into granules. The physical structure of the catalyst is an important factor in determining its efficiency, and if the mechanism governing the rate of entry of gases into the granules can be established it becomes possible to calculate the most suitable fineness of powder and size of granule. The rate of entry of the gases has been determined by measuring the transient rates of Knudsen flow and adsorption of water, ethanol, and isopropanol vapours in beds of alumina and thoria during periods of time as small as one millisecond. The measured rates have a negative temperature coefficient, are first order with respect to pressure, and certain of them are second order with respect to the amount of adsorbent. The adsorption of gases on metals has been treated theoretically and the results have been used to suggest the mechanism of the Fischer-Tropsch process by which carbon monoxide is hydrogenated to produce liquid fuels.

(*d*) *Fine Particles.*—The separation of finely divided solids from gas or liquid suspensions is a problem common to many industrial processes. Experimental and theoretical studies have shown that the sedimentation of particles in suspensions is closely correlated with the flow of liquids in filter cakes and can be used as a basis for estimating the efficiency of filtration and improving the design of filters and filtration techniques. The separation of fine particles from gas streams has also been investigated and a new type of centrifugal separator has been developed which will effectively separate particles as small as two microns. Some field tests under industrial conditions have confirmed the results obtained in the laboratory. For this work a new type of thermal precipitator was developed for the quantitative measurement of concentrations of fumes.

(*e*) *Condensation of Steam.*—It is known that the efficiency of steam condensers can be greatly improved if the steam can be caused to condense on a suitably treated cooling surface as droplets rather than as a continuous film. No successful industrial unit has yet been operated on this principle and little is known of the way in which the droplets are formed, the most suitable agents for making the surface hydrophobic (water-repellent), or the conditions under which this surface can be maintained. Equipment has been built to determine the efficiency of agents causing the dropwise condensation, and the calorimetric heats of immersion of several hydrophobic solids have been measured.

6. Chemical Physics.

The work of this Section includes the application of spectroscopy, X-ray diffraction, electron diffraction, electron microscopy, and mass spectroscopy to the elucidation of the structure of molecules and of chemical behaviour. These methods are particularly fruitful in the study of the solid state and the role of defect solids in solid reactions, catalysis, fluorescence, &c. Continuous refinement of the instruments is made and the Section has made significant contributions to these techniques. In addition to work on the Section's main projects, 33 short-term projects were undertaken for industry, university departments, medical and scientific institutions, and other parts of the Organization. Eight guest workers have been accommodated in the Section for various periods during the year, and much fruitful collaboration has resulted.

(*a*) *Spectroscopy.*—The development of multiple monochromators of the type devised in this Section has proved so successful that several manufacturers of spectroscopic equipment in England and the United States of America have applied for licences to produce instruments of this type. An American firm is now marketing an infra-red spectrometer based on the multiple monochromator principle. A reflection microscope, designed to convert the existing infra-red spectrometer into a microspectrophotometer, has been constructed using reflection objectives made by the Division of Physics. This will have particular application to work on protein films. Service work has included the development of methods for studying deterioration in paint films; structural studies on alkaloids from indigenous plants, terpenes, sulphonyl halides, pulegons, and limonin; and numerous analytical problems.

(*b*) *X-ray Diffraction.*—The high-power gyrating-anode X-ray generator has been completed and installed. A high-temperature specimen holder for use with normal diffraction cameras has been developed.

The analysis of the structure of lanosterol—a constituent of wool wax—has been completed and the detailed stereochemistry derived. Other work has included the structural analysis of vermiculite (*see* Section 3 (*h*)), establishment of phase relationships in the thorium fluoride-potassium fluoride system, and identification of a series of long-chain fatty acids of industrial importance.

(*c*) *Electron Microscopy.*—The resolving power of the equipment has been further improved. Service work has included characterization of rabbit myxoma virus and its relation to vaccinia virus; establishment of distinction between viruses of Murray Valley encephalitis and myxomatosis; the morphology of peritrophic membranes, originating from the gut of insects; the morphology of plant and animal mitochondria, the sources of enzymic activity in living cells; characterization of a staphylococcal bacteriophage and study of the phage-cell relationship; and examination of products of kaolinite reactions.

(*d*) *Electron Diffraction.*—Electron lenses of new design installed in the existing electron diffraction camera have improved its versatility and resolving power. A second camera, incorporating an electron microscope, is being constructed for the study of submicroscopic particles. Novel schemes for the accurate measurement of the intensities of electron beams, required for structure analysis by electron diffraction, are being tested.

The method is of considerable value in the study of the structures of surface compounds and of extremely small crystals (100Å) and yields information, not obtainable otherwise, of value for the elucidation of chemical behaviour. Structural analysis of gold-oxygen phases and of various forms of alumina have been made.

It has been found that layer-lattice crystals, of which boric acid is a typical example, invariably show a high degree of disorder when the crystals are small. Methods for determining the nature of this disorder are being developed.

(*e*) *Mass Spectroscopy.*—Large sections of chemical industry are based on chemical reactions, the course of which depends on the strength of the bonds between the atoms. By means of mass spectroscopy the strength of these bonds and other related chemico-physical data can be determined. The energies of ionization, of excited electronic states, and of bond dissociation are being studied by the measurement of ion appearance potential curves. Automatic equipment designed for use with the mass spectrometer has improved the accuracy of the recorded data to a point at which unsuspected fine structure in these curves has been revealed; from this fine structure, which corresponds to the far untraviolet and soft X-ray spectra of the ions, deduction of excited states of ion fragments and the accumulation of data on the electron-induced ionization process has become possible. The mass spectrometer has also been used in a study of the mechanism of the photochemical decomposition of aliphatic ketones.

(*f*) *Optical and Luminescent Properties of Solids.*—A method of measuring simultaneously the temperature and wavelength dependence of the true absorption coefficient, refractive index, and photoconductivity of thin evaporated layers of crystalline solids has been devised and encouraging results have been obtained. By extension of these measurements into the vacuum ultraviolet region it is hoped to obtain fairly complete data on the significant electronic energy states of solids. This information is the basis of any understanding of the physical and chemical properties of defect solids. Parallel with these experiments the luminescent properties of crystalline solids are being studied by the use of the method of periodic excitation.

7. ORGANIC CHEMISTRY.

Wool and sugar-cane waxes and allied aliphatic compounds of high molecular weight, plant alkaloids, and phenol formaldehyde plastics have continued to be the main interests of this Section. The work on plant alkaloids has been chiefly directed to the chemical examination of plants poisonous to stock. The service provided for the microanalysis of organic compounds has continued to be widely used by industry and the universities. As the demand for analyses increases, it is hoped to include additional methods of analysis in the more satisfactory continuous operation. The new direct determination for oxygen is now on this basis.

(*a*) *Sugar-cane Wax.*—This wax is potentially available in considerable quantities in the filter muds from sugar-cane mills. Although an industrially useful wax can be produced after bleaching and refining, attempts have been made to prepare a number of derived waxes which should be of greater value to the wax industry, using as a starting material the mixture of long-chain fatty acids obtained by bleaching a vacuum-refined wax. The difficulties, mentioned in the previous Annual Report, encountered in converting this wax into a series of ester waxes have been overcome and they can now be readily produced. Representatives of several chemical groups have been prepared; mainly the esters and amides of poly-functional alcohols and amines. Some of these derived waxes show improved properties compared with the parent acids. Their physical properties and their behaviour in solutions and in gels are being examined to discover their usefulness and, if possible, to obtain information on the relation between their physical properties and chemical structure. In the patent literature many solvents have been claimed as suitable for the separation from the crude cane wax of a product resembling the original cuticle wax. Accurate measurements have been made of the solubility of sugar-cane wax in a range of these solvents, and the results indicate that acetone ethanol, and *iso*propanol are likely to be most suitable for a process of solvent refining.

Other investigations on fats and oils completed during the year include the examination of the seed fat of the cruciferous plant *Pringlea antiscorbutica* (Kerguelen cabbage), which is unique to the Kerguelen-Heard group of islands, and the identification of the oil called Tige oil by the natives of New Guinea as a mineral or petroleum oil.

(*b*) *Stock Poisons and Plant Alkaloids.*—A method for the quantitative study of variations in the alkaloid content of the hepatotoxic *Heliotropium europaeum* has been sought that would be suitable for use by the Division of Animal Health and Production in its physiological investigations. The paper chromatographic method referred to in the 1950-51 Report was ultimately abandoned in favour of column partition chromatography, which has proved highly successful. In addition to the alkaloids heliotrine and siocarpine and the N-oxides of these two bases, parion chromatography has revealed the presence of ree other alkaloids and their N-oxides.

Pyrrolizidine alkaloids also occur in the leguminous nus *Crotalaria* and, as recent field work tends to criminate *Crotalaria* species in connexion with imberley horse disease, an investigation of these ants has been commenced. Although *Atalaya miglauca* is no longer held responsible for Kimberley orse disease, its seeds have been shown to be extremely xic to horses and probably in the past *Atalaya* oisoning has sometimes been confused with the disease. onsequently the examination of *A.hemiglauca* is being ntinued.

The seeds of *Lupinus pilosus,* which has become aturalized and is a valuable fodder plant in parts of Vestern Australia, have been suspected as the cause f heavy losses among sheep in recent years. Examinaion of the seeds has revealed the presence of more than per cent. of alkaloidal material (including N-oxides), omprised of at least three alkaloids together with the V-oxide of one of them. One alkaloid and its N-oxide ave been isolated and identified.

The general examination of Australian alkaloidearing plants has been carried on side by side with he stock poison investigations. The bark of *Gyrocarpus americanus* contains, in addition to phaeanthine, the water-soluble quaternary base *d*-magnourarine. This alkaloid bears a close structural relationship to the important active principle of curare, *d*-tubocurarine, which may theoretically (and possibly enzymatically in the plant) be built up from two molecules of magnocurarine. From *Glycosmis pentaphylla* the two furoquinoline bases kokusaginine and skimmianine have been isolated. Structural work continues on cryptopleurine and a number of other alkaloids of unknown constitution.

(*c*) *Plastics Investigations.*—(i) *Kinetics of the Phenol-formaldehyde Reaction*—The study of the rates at which phenols and formaldehyde combine has been continued. The object is to discover the exact mechanism of this condensation, including the roles of the various catalysts. When these facts are known it may be possible to secure greater control over the course of the reaction and of the type of resin produced.

(ii) *Adhesives of Tannin-formaldehyde.*—In the 1950-51 Report it was mentioned that plywoods prepared with tannin-formaldehyde adhesives had been found to possess good strength and water resistance. They had the defect that when prepared they did not remain fluid for sufficient time to allow them to be applied to the veneers by mechanical glue-spreading rollers. It has now been found that, by heating the tannin solution with sodium sulphite, the viscosity can be diminished without affecting the subsequent reaction with formaldehyde. Modified in this way the mixed adhesive maintains its fluidity long enough for commercial requirements. The adhesive cures at a lower temperature than phenolic adhesives, and plywoods in which it is used have the water resistance conferred by phenolic adhesives. With this defect remedied the work has been concluded. The potential supply of tannins is being investigated by the New South Wales Forestry Commission's Division of Wood Technology, who have in hand also a survey of the tannin content of *Pinus radiata* bark, and of the barks of indigenous trees.

(*d*) *Products from Acetone and Ammonia.*—From the reaction between these cheap reagents potentially useful classes of organic compounds have been prepared. In the last Annual Report it was described how with increasing temperature the reaction between acetone and ammonia produced, in addition to tetrahydropyrimidine, considerable quantities of a tetramethyldihydropyridine. In that work an acidic catalyst was used and the products were contaminated with polymerized material. It has since been found that by the use of an alkali catalyst formation of the pyrimidine is completely suppressed and the tetramethyldihydropyridine can be obtained in over 60 per cent. yields. The properties and structure of this compound and of those produced from it by hydrogenation have been studied. The hydrogenated bases, which have features in common with some naturally occurring alkaloids of high toxicity, will be examined for possible uses as insecticides. This work has stimulated the interest of a large industrial company and it no longer appears necessary to continue this project.

8. CHEMICAL ENGINEERING.

During the year the leader of the Section resigned to accept a post in industry. Some rearrangement became necessary and officers engaged on certain problems of a fundamental physico-chemical nature were transferred to the Physical Chemistry Section, to which the staff of the high-pressure laboratory in Sydney is also attached. The research programme of the Section is at present confined to the complete gasification of Victorian brown coals to produce both synthesis gas and gas of high calorific value suitable for distribution as towns gas. An account of this work will be found in Chapter XIX., Section 7.

The process equipment laboratory, which is well equipped with pilot-scale processing plant covering most unit operations, has provided a useful service to other Sections and to industry. Fifteen guest workers from industry have spent short periods in the laboratory to use grinding, filtration, and spray-drying equipment. In addition the Section has dealt with numerous inquiries on chemical engineering and other problems.

XVIII. MINERAGRAPHY AND ORE-DRESSING.

1. GENERAL.

The Organization's work reported in this Chapter covers the determination of the composition of ores and of the most suitable methods of treatment. The mineragraphic work is reported in Section 2. The treatment investigations, which are made in collaboration with the Mining Department of the University of Melbourne and with the School of Mines, Kalgoorlie, are reported in Section 3 and flotation work by the Division of Industrial Chemistry in Section 4.

2. MINERAGRAPHY.

Twenty-eight investigations have been made into the mineral associations of rocks, drill cores, and mill products submitted by mining organizations and institutions. Several of these are related to the search for new mineral deposits and eight have been concerned with the experimental treatment of ores in the Ore-dressing Laboratories.

Mineral associations have been determined in ore samples from the New Butler's mine at Torrington, the Commonwealth mine near Wellington, the Spirit of Iron and Guy Bell mines at Drake, New South Wales, the Peninsula Hope mine in north Queensland, the New Ideal mine at Cordalba, the Totley mine at Ravenswood, Queensland, and the Coronet Hills mine, Northern Territory.

Assistance has been given to the preparatory work for the Empire Mining Congress in Australia in 1953, and Dr. A. B. Edwards has edited a large number of descriptive articles to form an authoritative publication on the geology of Australian ore deposits. Several articles have been contributed to the volume and one on the Costerfield antimony field led to further examination of Costerfield ore and the discovery of a gold antimonide aurostibite, in the ore. The gold antimonide has been found in a remarkable eutectic intergrowth with gold, and the temperature of formation of the artificial eutectic, 320° C., indicates that the gold antimonide was deposited at a higher temperature than the stibnite. The gold antimonide is largely disintegrated in the later stages of vein formation and it is probable that the rusty gold which is commonly observed in auriferous stibnite veins is the result of this breakdown. Rusty gold is distinguished by its reddish colour, from the yellow gold which occurs at Costerfield in quartz or as minute particles in the grain boundaries of stibnite crystals.

The core of a diamond drill hole at Peko mine, Tennant's Creek, has disclosed a copper ore body over a width of 20 feet, and an examination of the core has revealed the presence of notable amounts of cobaltite with the chalcopyrite and magnetite. Tetrahedrite, galena, and a lead-bismush compound are minor constituents of the ore, as well as small amounts of native bismuth and a silver-bismuth compound which occurs as an ex-solution product in the galena.

An examination of dolomite from the banded iron formation in the Middleback Ranges, South Australia, has disclosed significant amounts of manganese as a primary constituent, thus providing a likely source of the manganese found in parts of the iron ore bodies. The manganese occurs isomorphously substituted for iron, magnesia, or possibly lime in the dolomite.

Tungsten ore from Rye Park, New South Wales, contains crystals of wolfram, less than 1 mm. across, dispersed through a rock consisting chiefly of magnetite, green biotite, and quartz. The wolfram crystals are invariably surrounded by thin rims of scheelite, commonly only a few microns wide.

The investigations have been facilitated by contributions from a number of mining companies through the Australasian Institute of Mining and Metallurgy. The University of Melbourne has also co-operated in providing laboratory accommodation in the recent extensions of the Geology Department.

3. Ore Dressing.

Work done at Melbourne is recorded in 23 reports which refer to ores of gold, tin, tungsten, cobalt-nickel, copper-lead-zinc, antimony, bismuth, gypsum, and pyrochlore, and to lead furnace slags, beach sands, a filler for plastic products, brown coal, and lucerne seed.

The application of magnetic and electrostatic separation to the concentration of pyrochlore from an ore from Uganda was studied.

The application of sink-float and table concentration processes for the beneficiation of dune gypsum deposits in South Australia was investigated.

Attempts were made to develop leaching processes for recovery of bismuth from a Tennant Creek (Northern Territory) ore, and of cobalt and nickel from an ore from New Caledonia.

A polarographic method for determination of dissolved oxygen in cyanidation and flotation plant pulps is being developed; this technique could be useful for testing and control in many ore treatment plants.

The work at Kalgoorlie, in addition to 197 free assays or analyses, resulted in the issue of 45 reports of which 23 involved metallurgical investigation, including three pilot-plant trials. Most were concerned with gold ores and tailings and others dealt with recovery of scheelite and lead and zinc concentrates, beneficiation of limestone, and determination of characteristics of sand deposits.

During the year a considerable number of inquiries from the mining industry were answered by the Laboratory staff.

4. Flotation Investigations.

The study of the flotation process has been continued by the Physical Chemistry Section of the Division of Industrial Chemistry. When the tin mineral cassiterite exists in a finely disseminated form in an ore substantial losses occur when it is concentrated by conventional gravity methods. Two such ores, one from Ardlethan, New South Wales, and one from Maranboy, Tasmania, have been subjected to preliminary flotation tests using a process developed a few years ago in this laboratory. The Ardlethan ore, because of its high content of topaz, is not amenable to treatment by this process, but the tests on the Maranboy ore have given encouraging results and it is being investigated further.

The study of the process by which air bubbles and mineral particles become attached in a flotation cell has been continued. Since this process determines the capacity of a flotation cell, anything that can be done to increase the frequency of adhesion consequent on collision of air bubbles and mineral particles must have a direct bearing on the cost of treatment of the ore. It has been found that, as the bubbles approach closely to the mineral surface, the water between them flows away according to normal hydrodynamic laws, but at a certain critical distance the residual water film becomes unstable, and, with its rupture, adhesion between bubble and particle occurs. The thickness and hence the time required for rupture of this film depends on the degree to which the surface has been rendered hydrophobic (water-repellent). A closely related problem is the rupture of the thin liquid films comprising a foam. A new theory has been proposed which attributes a dominant role to the flow of liquid in the film under the influence of surface tension gradients across the film.

XIX. FUEL.

1. General.

Research on Australian coals by the Coal Research Section at Ryde, New South Wales, is reported in Sections 2-5. Co-operative investigations on the fossil pollen in brown coal made in the Botany School of the University of Melbourne are reported in Section 6. The work of the Division of Industrial Chemistry on the utilization of low-rank coal is reported in Section 7.

Coal Research Section.—The establishment of this Section began in 1948 with a small nucleus staff housed in temporary buildings. In September, 1951, the first permanent laboratory was occupied and a further building is nearing completion. Eleven additional research and technical officers were appointed, bringing the total scientific staff to 22. As a result the activities of the Section are now being materially expanded.

The Officer-in-charge, who was Australian delegate to the British Scientific Official Conference on Fuel Research in 1950, has been confirmed as Australian member of the Commonwealth Committee on Fuel Research, and in this capacity continues to act as co-ordinator of reviews of fuel research dealing with physical testing of coal and petrographic investigations generally and with work on brown and subbituminous coals. Liaison is also maintained with Australian and overseas standards authorities in work connected with the classification of coal and with the standardization of testing methods.

The Section has continued to assist the Joint Coal Board by examining a number of borehole cores.

Technical inquiries have been received during the year from government departments, public utilities such as gas works, &c., private consultants, university departments, and private individuals. They include procedures and types of apparatus used in the testing of solid fuel and its by-products; types, qualities, properties, and uses of coal from particular localities; and how to improve the quality of coal, coke, or gas, or how to minimize the deleterious effects of non-coal inclusions.

2. Examination of Coal Seams.

(*a*) *Western Field of New South Wales.*—On the Western Field several seams have been examined. The main seam in the field, Lithgow, has been examined by means of six pillar and nine channel seam samples, and one borehole sample. The Ulan seam (presumed to be correlative with the Lithgow seam) and the Katoomba and Lidsdale seam have also been investigated.

This preliminary survey of the Western Field will be completed when a cross-measure drift, which is at present being driven by a New South Wales State coal mine, provides the opportunity to obtain samples of the complete series of seams for testing and analysis.

(*b*) *Southern Field of New South Wales.*—A preliminary survey of the Bulli and Wongawilli seams of the Southern Field was commenced. To date six pillar and one channel seam sample and two borehole samples have been examined. Coal from several boreholes penetrating the top four seams has also been investigated.

(*c*) *Northern Field of New South Wales.*—(i) *Newcastle District.*—Cores from two boreholes penetrating the Wallarah, Great Northern, and Fassifern seams, have been examined in detail.

(ii) *Maitland-Cessnock-Glendon Brook District.*—The top of the Greta seam in this District, 6 feet in thickness, is generally left unmined because of its high sulphur content. It is very susceptible to spontaneous combustion and is a hazard in pillar extraction.

Three pillar samples from the top of the Greta seam have been examined in detail; the examinations included washability tests to determine the extent to which its sulphur content could be reduced by washing. These tests have indicated that from 40 to 90 per cent. of the total sulphur occurs in the organic form. The mineral sulphur is finely disseminated throughout the coal substance and would be difficult to remove by normal washing processes. Even if mineral sulphur were removed by cleaning after crushing the coal, the total sulphur content would not be reduced below approximately 2 per cent. because of the high organic sulphur content.

(iii) *Muswellbrook-Singleton District.* — Samples from trial shafts put down by the Joint Coal Board in this area have been examined. The shafts penetrated the Liddell, Barrett, Artie, and Ravensworth seams. These tests have indicated that, in the vicinity of the trial shafts, the Liddell seam and to a slightly less extent the Barrett seam are suitable for gas manufacture. The Liddell seam gave well-formed cokes in pilot-scale carbonization tests and has the unusually high hydrogen and volatile matter contents shown by the Greta seam.

3. Combustion Properties of Australian Coals.

This field of fuel utilization absorbs more than half the Australian deep-mine coal. It is not yet possible to predict the behaviour in use of Australian coals from the results of simple analysis or from abnormalities observed with respect to the methods of classification of coal used overseas. Because of this, and to establish correlation between coal analysis and usage, it is necessary to carry out a comprehensive survey of the ignition and combustion characteristics of Australian coals with particular reference to the evaluation of coal for combustion purposes. This work commenced in March. 1952, and satisfactory progress has been made. A laboratory furnace for the determination of ignition temperatures has been constructed and its method of operation standardized. A furnace for measuring the velocity of igniton of different coal types is nearing completion. Pilot-scale combustion furnaces are under construction for studying the burnability of coal fired in underfed and overfed fuel beds and in pulverized form.

4. Coal Constitution.

(*a*) *Permanganate Oxidation.*—Work overseas suggests that the reactivity of coals to boiling alkaline permanganate could be adopted as a measure of coal rank. An extension of this work to Australian coals has been commenced and has shown that the total oxidant consumption can be divided into (i) alkaline permanganate used to oxidize the coal, (ii) manganese dioxide precipitated, (iii) permanganate reduced by some of the oxidation products on acidification in the cold, and (iv) further permanganate reduced on boiling the solution. The alkaline permanganate consumption is best expressed as the sum of an initial rapidly completed reaction, a zero-order and a first-order reaction, and the sum of the two reactions on acidification as another zero-order reaction.

The amount of the initial reaction is simply related to the moisture content of the coal. This indicates that the physical and chemical factors responsible for the retention of moisture in the air-dried coal, and therefore for the internal surface area, are also responsible for the initial reaction with alkaline permanganate. There appears to be a relationship between the carbon content of the coals examined and the reaction rat e constant for the zero and first-order reactions with alkaline permanganate.

(*b*) *Physical Chemistry.*—Work has commenced on spectrographic examination of coal ashes for the detection of trace elements. A research officer has been appointed to do X-ray diffraction work and a literature survey of the field has been commenced.

5. Methods of Analysis.

Generally, the methods of analysis used by this Section are those specified by the British Standards Institution or by the British Fuel Research Station. However, other rapid methods are being investigated in order to expedite the work.

(*a*) *Pyrite and Sulphur Types in Coal.*—The rapid method proposed by the British Coke Research Association for the determination of sulphur types in coal has been investigated thoroughly and has been found to be more satisfactory than the more time-consuming British Standard Specification method.

The method has been extended to the determination of sulphur type, including ferrous sulphide, in coke.

The presence of magnetite in the coal has been found to interfere with the determination, as has the formation of some nitric acid oxidation products inhibiting the precipitation of iron by ammonia.

Some factors in the weathering of pyrite have been observed which indicate the necessity of analysis of coal for forms of sulphur as soon as possible after preparation of the analytical sample.

(*b*) *Determination of Phosphorus.*—Because of the time-consuming nature of the standard method for the determination of phosphorus in coal, investigations have been made into the possibility of using a colorimetric method based on the production of molybdenum blue. A procedure using 1,2,4-aminonaphthol sulphonic acid as a reducing agent was found to give satisfactory results in this determination.

(*c*) *Tar Analysis.*—Work has been commenced on the investigation of methods of analysis of coal tars. The moisture, specific gravity, total sulphur, and ash have been determined on a number of samples produced during the course of pilot-scale carbonization tests on various New South Wales coals.

6. Microstructure of Brown Coal.

Work on fossil conifers has been continued in the Botany School of the University of Melbourne; a paper has been submitted for publication.

7. Utilization of Low-rank Coal.

The Chemical Engineering Section of the Division of Industrial Chemistry has continued its investigation of the complete gasification of Victorian brown coals to produce both synthesis gas and high calorific value gas suitable for distribution as towns gas. Pilot-plant research is being supported by fundamental work on the properties of brown coals and the mechanism and kinetics of the chemical reactions involved in the complete gasification of coal. A new synthesis gas pilot plant employing a fluidized fuel bed has been completed and is now being used in a systematic study of oxygen-steam gasification in this type of system. It is intended that this study will be extended by the construction of a further pilot plant in which gasification will be carried out at pressures up to 20 atm. For this work information is required on the influence of superatmospheric pressures on the rate of the carbon gasification reactions, and the special reactor required for this investigation has been designed and is now under construction.

Further research has been carried out on the fusion and clinkering properties of brown-coal ash. Particular attention has been given to a study of the mechanism of the initial sintering of ash which may occur at temperatures 400–500° C. below the final fusion temperature.

A study of the catalysis of the water-gas shift reaction by which carbon monoxide and steam react to form hydrogen and carbon dioxide during brown coal gasification has shown that carbon surfaces exert practically no influence on this reaction, but that various types of brown-coal ash are very active catalysts. The active constituents in the ash have been identified and a tentative mechanism derived. A theoretical study has been made of the influence of several variables on the reactivity of carbon to steam, oxygen, and carbon dioxide. Particular attention has been given to the influence of ash constituents on carbon reactivity.

Research on the production of high calorific value gas is concentrated on the investigation of the rate and mechanism of methane formation during pressure gasification of brown coal. To this end it is planned to investigate the reaction of carbon monoxide-hydrogen mixtures with brown coal and brown-coal chars in fluid beds under pressures ranging from 15 to 50 atm. Most of the special high-pressure equipment required for this work is now constructed, and erection of the plant is well advanced. A programme of work on the fluid-bed carbonization of brown coal has been completed.

Several short-range co-operative research projects undertaken included an investigation of the fluid-bed carbonization of Leigh Creek sub-bituminous coal, aimed at the production of a low volatile pulverized fuel for use in an experimental slag dezincing furnace; an investigation of the utilization of high-moisture raw brown coals for the manufacture of producer gas for firing lime kilns; and an investigation of the suitability of low-ash brown coals for the manufacture of electrode carbon for the aluminium reduction industry.

Advice has been given to a number of organizations on the properties of brown-coal ash, and to one company on the use of wood fuel for producer gas manufacture.

XX. PHYSICAL METALLURGY.

1. General.

The Section continued to be housed in and to wo in close collaboration with the staff of the Baillie Laboratory in the University of Melbourne under th general direction of the Professor of Metallurgic Research.

The two main lines of investigation continue to b the study of titanium and its alloys and an analys of the mode of deformation of metals under prolonge stress, a phenomenon generally known as creep.

Titanium is a metal of increasing industrial im portance and Australian resources of raw material ar considerable.

Mr. H. W. Worner of this Section has been awarde the Syme Prize for original research for his wor on titanium alloys. The prize was shared with Dr A. Gottschalk of the Walter and Eliza Hall Institute

2. Titanium and its Alloys.

(*a*) *Alloys.*—Much of the year's work was directe to elucidating the general pattern of behaviour o titanium alloys. The study of alloys with metals hav ing an atomic size close to that of titanium is of valu for this purpose.

The metals chosen included silver, tin, tantalum niobium, and molybdenum. It was found that all these metals, with the exception of tin, caused a depression of the allotropic transformation temperature range. With tin there was a slight elevation of this temperature. Knowledge of this kind is necessary in order to control the heat treatment of the alloys to bring about changes in physical properties.

The results have shown that the low-temperature form of titanium does not obey the general rules relating to alloying. The solid solubilities of the various elements are lower than would be expected. The high-temperature form, however, appears to fall in line.

An exploratory study of the heat treatment of alloys of silver and of tin with titanium showed that they could be hardened to a small though useful extent by simple quenching from the β-phase region.

(*b*) *Reaction with Air.*—This is of technological importance since the high temperatures at which alloys are likely to be employed and the hot working in fabrication will result in surface hardening from reaction with both oxygen and nitrogen.

The rate of absorption of oxygen has been measured under controlled conditions of temperature and pressure. Further, the structure and composition of the resulting scales have been determined by X-ray, microscopic, and chemical techniques.

The rate of absorption of oxygen at 760 mm. pressure between 600 and 1,000° C. follows an approximately parabolic law.

It has also been found possible to melt titanium dioxide in the argon arc furnace. By diluting this with excess titanium various melts covering the composition TiO, Ti_2O_3, and TiO_2 have been made and studied.

(*c*) *Analytical Methods.*—Satisfactory methods for determining aluminium, calcium, and magnesium in low concentrations in titanium have been worked out. Investigations on the estimation of tungsten are in progress.

Chemical methods are also being used to strip scale from the surface of metallic titanium in connexion with the oxygen surface-reaction work.

3. Slow Deformation of Lead and its Alloys—Creep.

Further study of the influence of thallium on the creep of lead has revealed the importance of grain size. The influence of this factor is found to predominate when the thallium concentration is less than per cent. Between 10 and 30 per cent. the rengthening effect of the solute is more important nd with higher concentrations the tendency to interystalline cracking is the governing characteristic.

The relative movement of crystals in the surface of st pieces under stress has been demonstrated by veral techniques. Examination of the interior of test ieces at the end of a period of months under stress ows also relative movement of crystal grains. A new oservation shows how, under prolonged stress, crystal apes may be modified so that they remain in contact hilst accommodating these relative movements. If is adjustment of shape is not possible under the conitions intercrystalline cracks form.

In connexion with this work on deformation, special ptical techniques have been further developed and ome attention has been given to the deformation of luminium and zinc to which these techniques are ore readily applied.

XXI. TRIBOPHYSICS.

1. General.

Division of Tribophysics.—The work of the Division as continued for the most part along the lines escribed in last year's Annual Report. Major dvances have been made in our understanding of the istortions in a metal produced by plastic deformation, f phase changes in metals, and of the mechanism of low combustion of hydrocarbons. Some projects had o be abandoned for economic reasons.

It is hoped that the new laboratory will be ready arly in 1953. In the meantime the facilities of the Chemistry Department of the University of Melbourne are still being used. Sincere thanks are due to Professor Hartung and the University of Melbourne for their continued hospitality. We are greatly indebted to the Physics, Metallurgy, and Engineering Departments for the use of many facilities.

Assistance and advice have been given to industrial firms, Government organizations, and University departments on a wide range of problems of lubrication, bearings, metallurgy, combustion, electronics, and electrolytic polishing. Two officers conducted a symposium on the lubrication of metal surfaces arranged jointly by the Brisbane branches of the Australian Institute of Metals, the Australasian Institute of Mining and Metallurgy, and the Institution of Engineers, Australia. Members of the Division are acting on various committees, in particular the Engineering Group Committee. The metallurgical colloquia held with other metallurgical groups continue to be an important medium for the exchange of specialized knowledge.

2. Properties of Surfaces.

One of the main aspects of this work is the investigation of the effects of atomic arrangement (crystal orientation) on surface properties.

A study of some practical aspects of friction and lubrication has yielded valuable results. Work is also being done on diffusion on solid surfaces and on the properties of surface films of long-chain compounds and of silicone lubricants, properties which are important for lubrication, detergency, and surface protection.

(*a*) *Bearing Testing.*—Several factors affecting the performance of sleeve bearings, particularly in the transition from hydrodynamic to boundary lubrication conditions, have been investigated. These include surface finish of the journal, type of bearing material, mode of "running-in", and geometric properties such as clearance ratio. Two different bearing materials, tin babbit and cadmium silver, have been used. During run-in under the particular test conditions, bearings of small clearance ratio (of order 4,000) obtain a high load-carrying capacity more rapidly than those of larger clearance. In a bearing subjected to a constant, unidirectional load the effect of slight wear and deformation of the bearing metal during run-in is to produce a smooth area with curvature tending to equality with that of the journal.

(*b*) *Spreading of Liquids on Solids.*—The surface mobility of liquids on solids has been studied by direct observation of the rates of spreading of drops placed on a horizontal metal surface. Consideration of the problem of spreading drops shows that spreading, when it occurs, does so by two mechanisms, first by a gravity process and then by surface diffusion. Experiments are continuing.

(*c*) *Surface Free Energy of Solids.*—The surface free energy of solids is being determined by observing the rates of changes of length of fine fibres extruded into a thermostated vacuum chamber. The change in length results from two opposing forces: one tends to shorten the filament so that its surface free energy is decreased, and the other to lengthen it because of its weight. The surface free energy is calculated from the critical filament length at which no change in length occurs. Results on paraffin wax show that the surface free energy changes abruptly on melting and that its temperature coefficient is similar in the solid and the liquid states. Experiments with coarse crystalline tin are in progress.

(*d*) *Catalysis on Single Crystalline Surfaces.*—The influence of the arrangement of the atoms in a solid surface on its catalytic properties is being investigated. The preparation of single crystals in the form of thin sheets enables kinetic experiments to be carried out with surfaces of uniform atomic arrangement, the nature of the arrangement depending on the orientation of the individual crystal. A study is being made of the zero-order decomposition of formic acid vapour over silver. The experiments so far indicate that both the rate and the activation energy of the reaction depend on the crystal orientation, but the nature of the relationship is not yet clear.

3. Metal Physics.

The aim of the work in this field is to obtain a better understanding of the properties and behaviour of metals and alloys. There are two main ways of changing the properties of metals, plastic deformation and phase transformations, and it is with the mechanisms of these two phenomena that the work of the Division is concerned.

(*a*) *Plastic Deformation.*—The motion of certain lattice defects is generally held responsible for the occurrence of plastic deformation. However, as details of these defects and their effects on the properties are still unknown, various experimental methods are being used to elucidate their type and arrangement.

(i) *Shape of X-Ray Interference Lines.*—Work has continued on the accurate determination of the line shapes of annealed and deformed specimens. The X-ray output of the set has been stabilized to within ± 1 per cent. and, in addition, a monitor of the primary X-ray beam has been constructed and is being used to compensate for the small variations that still occur in the X-ray output.

To assist in the setting up of the spectrometer for each experiment a device has been designed and incorporated into the instrument to permit continuous scanning and recording of the X-ray diffraction pattern.

(ii) *Energy stored in a Metal during Deformation.*—The apparatus constructed for measuring this energy has been working satisfactorily and the results obtained for copper, deformed by torsion, are more accurate than those of previous workers. The stored energy increases with deformation in a similar way to the torque required to produce the deformation; there appears to be a simple relation between the stored energy and the work hardening. Small amounts of some impurities in the copper are responsible for large differences both in the recrystallization temperatures and in the shapes of the curves showing the release of stored energy as a function of temperature, but the total stored energy is not changed markedly. Other impurities, however, produce a significant alteration in the stored energy. The effects of various other factors are now being investigated with a view to obtaining information concerning the distortions remaining in the crystals after deformation.

(iii) *Changes in Electrical Resistivity due to Cold Working.*—The anisotropy of electrical resistivity induced in cubic metals by deformation, which was first observed in rolled strip, has also been found in hard drawn wires. In collaboration with the Division of Electrotechnology the resistivities have been measured in the transverse direction of the wires. An analysis of these results and those discussed in last year's report suggests that plastic deformation produces regions of faulty stacking of the atomic planes in the crystals and that these faults are mainly responsible for the change in electrical resistivity.

(iv) *Recrystallization.*—Direct observation by means of polarized light of the recrystallization of metal specimens has shown that the growth of new crystals is frequently erratic. The possible connexion of this erratic growth with the inhomogeneity of deformation within the crystals of a polycrystalline aggregate is being studied. It has been necessary to refine the technique of microscopy with polarized light in order to observe these inhomogeneities.

(v) *Micro-indentation Hardness Tests.*—The hardness tester, built in the Division, which employs very small loads and correspondingly small indentations, is being used to investigate the effects of the inertia of the indenting system and of the rate of approach of the indentor to the specimen on the results obtained in hardness tests of this type. It has become clear that insufficient attention has been paid to these variables in the past.

(*b*) *Phase Changes.*—Phase changes in solids are of two types. In the first type the nucleation and growth of the new structure are effected by means of the thermal movement of the atoms. In the second type, thermal movement plays no part and the transformation can occur extremely rapidly at very low temperatures. The second type (martensite transformations) occurs by small displacements of atoms relative to each other so that each atom in the new structure has the same neighbours as it had in the old. These atom displacements can be deduced from various observable geometrical features of the transformations.

A theoretical study of martensite transformations has been carried out and the theory developed predicts successfully all the observable geometrical features of the transformations to which it has so far been applied.

Two transformations of the first type are being investigated experimentally, viz. the order-disorder transformation in copper-gold and the precipitation in supersaturated copper-beryllium allows. The theoretical analysis developed for martensite transformations has now been applied to the copper-beryllium precipitation and excellent agreement has been obtained between the predicted geometrical features and those determined experimentally.

It seems, therefore, that the two types of transformation are geometrically similar.

4. Reaction Kinetics.

(*a*) *The Slow Combustion of Organic Compounds.*—The mechanism of the reaction involves the preliminary formation of unstable peroxides. These subsequently decompose, and in doing so, catalyse further oxidation. Little more than this broad outline is known and detail of the reaction steps and of their interrelation ar lacking. The problem is being approached by kineti studies of the separate reaction steps in isolation, th work so far having been concerned with the initial par of the reaction. The kinetics of oxidation of benzaldehyde in solution, a system in which the formation o peroxide is not complicated by decomposition or autocatalysis, have been examined in detail. These experiments have been accompanied by a parallel investigation of the oxidation of simple hydrocarbons with the object of ascertaining to what extent the comparatively simple kinetic behaviour of the liquid-phase oxidation is reproduced in the gas-phase (slow combustion) reactions.

(i) *The Kinetics of Oxidation of Benzaldehyde to Hydroperoxide in Solution.*—The reaction proceeds by a chain mechanism, the chains being exceedingly long. This is reflected in extreme sensitivity to the presence of inhibitors. Addition of dibenzoyl peroxide causes an increase in rate. The peroxide-catalysed reaction is a free-radical chain reaction, the chains being terminated by mutual neutralization of two radicals. In the absence of catalysts, the kinetic behaviour is different and the reaction rate depends in a characteristic way on the concentrations of aldehyde and oxygen. The mechanism of the uncatalysed reaction is still in doubt, but it appears that the chain carriers are different from those involved in the catalysed reaction.

(ii) *The Kinetics of Oxidation of Simple Hydrocarbons in the Gas Phase.*—The kinetic characteristics of the first stages of the reaction depend on the rate of accumulation of intermediate compounds which subsequently catalyse the reaction. In the oxidation of propylene two such substances appear to be involved, the formation of one of these is counteracted by its decomposition at the vessel wall. The overall rate of accumulation is therefore determined by the diffusivity of the gas mixture and by the activity of the solid surfaces present. The latter effect accounts for the erratic behaviour commonly found with slow combustions. The rate of generation of the substance depends on the concentrations of reagents according to the same relationship as that found for the uncatalysed benzaldehyde oxidation. This suggests that the intermediate is a hydroperoxide. The nature of the second intermediate is more obscure. Its rate of accumulation is not influenced by diffusion to the vessel wall and depends on the reagent concentrations in a manner which seems to have no counterpart in the liquid-phase oxidations.

(*b*) *Thermal Conductivities of Organic Vapours.*—Conductivities at various pressures have been determined. Results for both polar and non-polar compounds indicate that the variation of conductivity with pressure is, in all cases, related to the variation of specific heat. The measurements permit the calculation of the intermolecular forces of the vapours. Experiments of the same type with vapour mixtures are in progress.

XXII. NATIONAL STANDARDS LABORATORY.

An account was given in last year's Annual Report of the establishment of the National Standards Laboratory and of the statutory functions of the Organization in the maintenance of the Commonwealth standards of measurement which are carried out in the Laboratory. These functions are shared by the Divisions of Metrology, Physics, and Electrotechnology, which together comprise the National Standards Laboratory.

The *Weights and Measures* (*National Standards*) *Act* 1948 provides for the States to administer, as in the past, weights and measures matters relating to trade and commerce, but it will be necessary for the State standards to be derived from the Commonwealth standards. In preparation for the proclamation of the Act, an informal conference with the Superintendents of Weights and Measures of the States was arranged at the Laboratory in June under the auspices of the National Standards Commission. All States were represented. The general effect of the new legislation on the technical problems of weights and measures administration and the derivation of State standards from those held by the National Standards Laboratory were discussed.

Through the National Standards Laboratory the Commonwealth maintains close liaison with the Bureau International des Poids et Mesures, and the Laboratory has recently received and accepted an invitation to take part in an international comparison of end-standards of length.

The Laboratory plays an important part also in the activities of other international scientific and technical bodies, particularly those of the International Standards Organization. This is done by contributing knowledge and services of the staff to the Standards Association of Australia and, where possible, by attendance at meetings of the I.S.O. overseas. During the year an officer of the Laboratory was the Australian delegate to the I.S.O. Committee on laboratory glassware and related apparatus.

Details of research work carried out in the constituents Divisions are given in the following three chapters.

XXIII. METROLOGY.

1. General.

As part of the National Standards Laboratory the Division of Metrology is responsible for the Commonwealth standards of measurement of length, mass, and time, and of the associated physical quantities. The Division maintains close collaboration with the Standards Association of Australia and the National Association of Testing Authorities.

The main effect of the Division has been directed towards meeting statutory requirements in respect of National Standards. The setting up of the geodetic base has been completed and some experience has been gained in its use. Satisfactory progress has been made in the production of the working standards of mass after considerable delay in obtaining the equipment required for finishing the weights. The reference and working standard kilogram were compared with the primary standard of mass, the platinum-iridium kilogram No. 44.

An informal conference was held between the National Standards Commission and the Superintendents of Weights and Measures of the six States to discuss the effect of the Commonwealth Weights and Measures Act and the States' activities. Officers of the Division were invited to the conference, and a considerable amount of work will be undertaken to assist the State departments to meet requirements of the Act.

2. Length and Associated Quantities.

(*a*) *Universal Comparator.*—A minor modification has been made which permits the observation platform to be locked in position, thus eliminating transmission of vibration to the tanks. Efficacy of temperature control of the room is being investigated by measurement of the effect of variations of ambient temperature on the length of the beam carrying the microscopes.

(*b*) *Dividing Engines.*—Further progress has been made in developing techniques for the ruling of very fine lines on metal and on glass. In particular, a number of scales of 250 lines at intervals of 0.001 inch have been ruled on chromium-plated steel for use in checking the micrometer microscopes of hardness-testing machines. A technique has been developed for the production of graticule scales in which lines about 0.00015 inch thick are formed by the deposition of chromium on glass.

(*c*) *Geodetic Base.*—The final alignment of the base was completed during the year, and a preliminary calibration was made in terms of the four-metre invar standard. This revealed some disturbing features in the base and steps were taken to rectify the installation. Auxiliary equipment for use with the base is being designed, and attention is being given to the problem of obtaining uniform temperature conditions over the full length, 50 m., of the base.

(*d*) *End Standards.*—The regular programme of maintenance of end standards has been continued. Owing to secular change, mentioned in a previous report, of two reference end bars some difficulty has been experienced in completing this programme and steps have been taken to make up a second set of reference end bars.

Eight sets of slip gauges, which have not been used since they were measured in 1947, have been re-measured to determine secular change. With a few exceptions these gauges were found to have a high degree of stability.

(*e*) *Measurement of Gears and Examination of Large Gear-Hobbing Machines.*—Two large gear-hobbing machines have been examined on behalf of the Department of the Navy; it was necessary to make up special equipment for this work. Subsequently, a double helical gear of diameter 12 feet was examined on behalf of the Navy.

Mathematical investigations on the geometry and measurement of gears and hobs have been continued, and a nomogram has been designed to facilitate calculations on helical gears. Tables giving base-circle diameters of gears with a 14½° pressure angle have been completed, and tables for gears with other pressure angles are being constructed.

(*f*) *Interferometry.*—Multiple-beam interferometry has been used in the measurement of vibration and in the study of the surface structure of metal surfaces.

Various forms of the new isotopic mercury 198 lamps have been received from the United Kingdom and America for investigations on their suitability as sources of high-quality wavelength standards. These standards are being considered internationally as ultimate units of length, and equipment is now being prepared for these investigations. In connexion with this general object, the Division has been invited to participate in an international comparison of length standards by interferometry which has been initiated by the Bureau International des Poids et Mesures, Sèvres, France, and immediate preparations are being made to carry out this work.

(i) *Calibration of Angle Gauges.*—The calibration of complete sets of angle standards by interferometry is being reported in a paper. This includes an exhaustive study of the distortion that occurs in the surfaces when the standards are used.

(ii) *Vibration Measurement by Multiple-beam Interferometry.*—The calibration by interferometry of an experimental type of vibrometer has been satisfactorily completed. The method is direct, convenient, and highly precise, and provides an absolute basis for vibration measurement. A paper describing fully the equipment, techniques, and results is being prepared for publication.

(iii) *Wavelength Interferometer.*—A very thorough test has been made of the photographic method for recording simultaneously the interference patterns in the various radiations used with the wavelength interferometer by putting it into routine service. This method is resulting in more accurate and more reliable work. The permanent record obtained is an important advantage.

(iv) *Kösters Interferometer.*—A modified Kösters interferometer has been completed and is being used to determine lengths greater than 1 inch. Preliminary tests have shown that interference fringes are observable with a 12-in. end gauge when a krypton light source cooled in liquid air (—180° C.) is used. Investigational work is proceeding with various light sources, including mercury 198 lamps. This instrument extends greatly the range of lengths measurable by interferometry in the Division, and will be used ultimately in routine standardization of end standards.

(v) *One-metre Interferometer.*—Experimental work is being done on the use of multiple-layer films in the Fabry-Pérot reflection interferometer which will be used in this project. Associated with this work is an investigation on the determination of the refractive index and thickness of thin films.

(vi) *Determining Long Lengths by White-light Interferometry.*—An investigation has been completed on the use of white-light fringes of the "channelled spectra" type in improving the precision with which long lengths can be determined by optical multiplication methods.

(vii) *Surface Structure of Lapped Steel Surfaces.*—A range of finely lapped steel surfaces has been examined for surface structure by a simple micro-interferometric technique. This work has shown that this simple method gives better results than certain equipment used overseas. In its present form the equipment is suitable only for laboratory use, but consideration is being given to methods of producing a robust instrument for wider use.

(viii) *Adhesive Films between Metal Surfaces.*—Investigation of the nature of the adhesive films (called "wringing" films) used throughout length metrology is proceeding. Metal surfaces after wringing have been examined by multiple-beam micro-interference methods and show extensive damage. An electrical method has been used to try to determine the thickness of such films. The work so far indicates that the conception of a wringing film actually separating the surfaces may be incorrect, and that the "separation" of two metal surfaces in wringing contact is mainly a function of the degree of crushing of the metal asperities on each surface. The design of equipment for measuring the normal and tangential forces which exists when surfaces are in wringing contact has been completed.

(ix) *Examination of New Dispersion Equation for Air.*—A new dispersion equation for air recently derived overseas has been critically examined and applied to the wavelengths in the visible spectrum of mercury 198. The examination shows that the new equation does not alter length determinations based on earlier equations by more than 1 part in 10^9.

(x) *Coating Plant.*—The coating plant has been used for depositing metallic and non-metallic films for a variety of purposes. Satisfactory graticules are being produced by depositing chromium and zinc by evaporation. In this way satisfactory lines about 0.00015 inch wide which do not rub off with deliberate mechanical abrasion are produced on glass. Other metals that have been deposited by evaporation are nickel, copper, silver and aluminium. Films of zinc sulphide, cryolite, and magnesium fluoride have been deposited on glass for use in interferometry.

(xi) *Excitation and Control of Discharge Lamps.*—Work on a continuously variable controller for krypton lamps has been completed and two controllers are now in operation in the Division. These equipments supply 1,500 V. r.m.s. at currents in the range 15-80 mA. at 50 c/s. Since the current is continuously variable, they may be used to excite any discharge lamp operating within the specified range, and they have been successfully applied to the excitation of cold-cathode mercury 198 isotope lamps. A design has been prepared for a simplified exciter with non-variable output for applications where the lamp is installed in a permanent set-up.

A very high frequency exciter for electrodeless mercury 198 lamps has been designed and is partially built. This equipment is intended to supply 100 W. at 200 Mc/s. A sub-unit containing an oscillator and frequency multipliers is now operating.

(xii) *Test Work.*—Optical flats and mirrors have been tested for industry and for another Division of C.S.I.R.O.

(*g*) *Capacitance Displacement Meter.*—Capacitance displacement meter type A has been sucessfully used in various applications. This work, together with studies made into the operation of parallel-plate capacitive transducers, has led to the development of a method whereby a given displacement may be calculated in terms of the output voltage or current from the displacement meter when the plate area of the transducer is known. The displacement meter may thus be used to calibrate the transducer, and this feature is of great value in transducers where the air gap is otherwise difficult to measure or direct calibration is not feasible.

A simplified, compact, and portable instrument, type B, in which rarely used features are eliminated, has been designed.

A recorder amplifier is being developed which will allow a normal recording milliammeter to be used in conjunction with the displacement meter. This unit may be used separately for other work if desired.

(*h*) *Lapping.*—The experimental elutriator mentioned in the previous Annual Report has been completed and has proved extremely satisfactory in the grading of fine abrasive powders.

Some experimental confirmation has been obtained of the theory which has been developed of the charging and the cutting action of a lap. The application of this theory to the preparation of experimental lapping plates has led to the production of lapped surfaces of a quality not previously achieved.

A technique ensuring the accurate reproduction of the desired geometrical form has been developed for the production of surface-finish standards. These standards can be measured absolutely by interferometric methods, and should be of value in the calibration of stylus-type instruments used for the measurement of surface texture.

(*i*) *Photogrammetry.*—A number of requests for assistance in this type of work have been received in addition to requests for the calibration of cameras. Permanent equipment is now being finally assembled.

(*j*) *Machine Tools.*—Many lathes have been examined for compliance with Customs Department specifications, and testing methods have been improved.

(*k*) *Measurement of Surface Texture.*—Further work is in hand on replica techniques for the measurement of surface texture. A mathematical investigation has been made of the actual profile recorded by a stylus of finite size traversing a square-groove calibration standard.

(*l*) *Measuring and Consultative Service.*—(i) A Matrix screw pitch measuring machine has been modified to allow measurements to be made on both plug and ring screw gauges of diameters up to 20 inches. This equipment will be particularly useful in the measurement of A.P.I. gauges.

(ii) Measurements were made of five datum points over a length of 196 feet set up for boring one propeller shaft of No. 1 Daring Class destroyer. Similar measurements were made over a distance of 250 feet of the misalignment of the engine bearings and propeller stern bush of a damaged ship.

(iii) Measurements were made at the Warragamba pumping station of the relative positions of a number of large pipe flanges. The measurements had to be made without interrupting the plant, and their purpose was to permit modifying equipment to be manufactured and installed with a minimum disturbance to the operation of the station. Special equipment was developed for this work.

(iv) Equipment submitted for test included sets of slip gauges, combination end bars, limit gauges, surface finish specimens, and a wide variety of measuring instruments and other equipment.

(v) Advice has been given to a number of industrial organizations on equipment and techniques of measurement and on the setting up of standards rooms.

(vi) Four courses in metrology are being given by officers of the Division at the Sydney Technical College and New South Wales University of Technology; laboratory work has been included for the first time in some of these courses.

3. Mass and Associated Quantities.

(*a*) *Maintenance of Standards of Mass.*—The reference and working standards of mass have been compared with the primary standard, the platinum-iridium kilogram No. 44. The values of all the working and reference standards were confirmed; certain deficiencies in the comparison equipment were noted and are being rectified.

(*b*) *Investigations on Balances.*—The difficulties mentioned in the previous Report as being due to the stirrup planes of balances distorting in their mounts have recurred. It appears that the only satisfactory course is to redesign the stirrup completely in such a way as to permit the plane to be finally lapped and polished after it is fixed in its mount.

The 100-kg. balance has been reconstructed; preliminary investigations indicate that its performance will now be satisfactory.

Work has been completed on the effects of knife-edge radii, on the dip of the beam, and ratio of effective lengths of the arms with the inclination of the beam. Work has commenced on plastic and elastic deformation of knife edges under load.

(*c*) *Barometry and Pressure Measurement.*—The demands from industry for this type of measurement have increased substantially, and special equipment is being designed. It includes a long range gauge barometer based on National Physical Laboratory design, a pressure vacuum vessel to accommodate mercury barometers, and a pressure controller.

(*d*) *Volume Measurement.*—In large capacity measures of the type used by Departments of Weights and Measures, errors due to distortion of the glass strike plate are possible. These errors have been investigated experimentally and found to be negligible.

Attention has been given to the design of automatic volumetric equipment suitable for use in weights and measures work, and a model of one type has been constructed.

(*e*) *Density Measurement.*—Work has been done with the density balance and bath to determine the limitations of this equipment. It has been found that the stirring of the working liquid is adequate to prevent stratification, and that the balance becomes critically damped when a liquid of viscosity 35 cP. is used in the bath. Despite this, satisfactory results have been obtained in liquids of much higher viscosity.

(*f*) *Calibration and Consultative Service.*—The quantity of test work received was about the same as in the previous year. There was a significant increase in the quantity of special work relative to routine test work. Advice and assistance have been given to organizations on the design and manufacture of equipment and on the suitability of commercially available equipment for specific purposes.

4. Rating of Time Pieces.

A satisfactory procedure in which autographic methods are used throughout has been developed for the testing of stop-watches. Some work has been done on the development of an autographic method for the rating of time-of-day watches by using an electronic counter to read the difference between the standard clock and the timepiece under test. Some of the equipment for this work is being made in the Laboratory workshop.

5. Applied Mechanics.

Research has commenced on engineering design analysis and machining, and developmental work has been continued on instruments and techniques for the precise measurement of engineering quantities such as force, pressure, stress and strain, angular speed, hardness, and vibration. The interferometry and capacitance methods of measuring small vibrations have been further developed.

Materials-testing machines and instruments for the engineering and allied industries have been examined and verified.

(*a*) *Engineering Design Analysis.*—Experience in industry has pointed to the need, firstly, for a wider application in design of logical methods of analysing the functioning requirements of engineering products in terms of limits and tolerances for the detail parts concerned, and secondly, for the development and the wide application of a series of basic engineering standards dealing with limits and fits, gauging principles, screw threads, surface finish, and drawing practice. The Division commenced research in this field when it participated in the Engineering Production Convention held by the Institution of Engineers, Australia, in Sydney in May, 1951 to discuss production economy through basic engineering standards. The proceedings of this convention have been edited by an officer of the Division and have been published by the Institution of Engineers, Australia.

During and subsequent to this convention, the Division, with the co-operation of engineering firms, conducted an analysis of industrial design and drawing practice to explore the economies that might be achieved. by the application of a proper analysis in design and the adoption of a common series of basic engineering standards in industry. This analysis confirmed that considerable economies might well result, a feature of the project being the effectiveness of the "design problem" technique which was developed specially to ensure recording of reliable information from the participating firms. The results of this analysis have now been published. The success of this project has influenced the Institution of Production Engineers to establish a working group to develop the analysis on a broader scale so as to obtain results truly representative of the New South Wales engineering industry as a whole. Officers of the Division are actively participating in this work.

(*b*) *Machining.*—The first project on machining was started, taking the form of a review of some overseas developments in surface finish with particular reference to the finish of machined surfaces. This work was undertaken for the conference on the finish of machined surfaces held in Sydney in May, 1952 and organized by the Sydney Division of the Department of National Development. The paper is being prepared for publication.

(*c*) *Vibration Measurement and Isolation.*—Two methods for the accurate measurement of small vibrations are being developed in the Division, one depending upon the observation of vibrating fringes in an interferometer system and the other making use of electrical capacity change. The latter has been applied in the design of a horizontal and a vertical vibrometer made in the Division. Good progress has been made with both methods, the interferometric method having been applied successfully to the fundamental calibration of the capacity-type horizontal vibrometer up to double amplitudes of the order of 0.0005 inches (50 fringes). A paper has been prepared for publication.

In pursuing the former project a special adjustable mount was developed to give fine control in setting the vibrometers. A paper describing the mount has been submitted for publication.

Further investigations have been made into the characteristics of two types of electromagnetic vibrometer which have been developed at this Laboratory and improvements in mechanical and electrical details have been made. A paper has been submitted for publication.

Because of a persistent demand from industry for advice and assistance in problems of vibration isolation, a survey of available information on the theory and practice of vibration isolation is being prepared for publication.

(*d*) *Stroboscope Driving Amplifier.*—This equipment has been completed and is used to excite stroboscopic lamps in the Division from a low-power, low-voltage source such as the crystal clock. In addition, facilities have been provided to operate the equipment as a sine-wave voltage or power amplifier, the output for a stroboscope having a peaked waveform.

(*e*) *Low-frequency Power Amplifier.*—This unit is intended to excite a shake table for vibration studies. A unit has been designed, built, and some developmental work carried out. Satisfactory operation has been obtained and the equipment has been put into service. It is hoped to carry out further developmental work to obtain higher undistorted power output.

(*f*) *Measurement of Physical Quantities for Industry.*—(i) *Force.*—Negotiations have continued for the construction and installation of a 50-ton deadweight machine for the calibration of proving devices. The 5,000-lb. proving ring has performed satisfactorily in service. A ring of lower capacity is required to extend the existing range of proving equipment, and a 1-ton ring has been designed.

(ii) *Pressure.*—The installation of apparatus for the calibration of pressure gauges within the range ±1 atm. has been completed and is in service.

(iii) *Stress and Strain.*—Apparatus employing photoelastic methods for stress analysis has been developed jointly by this Division and the Aeronautical Research and Defence Research Laboratories of the Department of Supply.

(iv) *Angular Speed.*—Further accessories have been constructed for use with the tachometer calibrator, including electrical apparatus to make use of timing pulses from the Laboratory crystal clock. A paper describing the apparatus and dealing with the interpretation of stroboscopic images has been submitted for publication.

(v) *Hardness.*—The use of test blocks of known hardness for checking the performance of hardness-testing machines, although not in itself a complete verification, is a very useful and common practice. A precision hardness-testing machine of National Physical Laboratory design is therefore being made for the calibration of these test blocks on the Rockwell principle.

The complete verification of hardness-testing machines involves the examination of the indenter geometry and of the instrument for measuring the resulting indentation, together with the determination of the applied load. Work has been directed towards improving the methods available for complete examination and towards the development of new methods of indenter load measurement. One type of hardness-testing machine employs a microscope for measuring the indentation and special scales made in the Division are available for checking such microscopes. Another type of machine measures the depth of penetration of the indenter and equipment is being developed for verifying such measurements.

A paper dealing with the diamond pyramidal hardness testing of spherical specimens has been submitted for publication.

Work directed to improving the accuracy of hardness testing of rubber is in progress.

(*g*) *Verification of Materials-testing Machines and Equipment for Industry.*—The examination of materials testing machines on behalf of the National Association of Testing Authorities and of the Services Inspection Authorities, and for private firms, continues to represent a considerable proportion of the work of the Section. In addition, many types of portable engineering instruments and equipment were calibrated.

(*h*) *Survey of Dynamometers.*—The Engineering Group Committee of C.S.I.R.O. and the Department of Supply has noted that frequent inquiries have been received from industry for dynamometer power testing of engines, tractors, and the like. This Committee considers that some service might be done for Australian industry if the facilities available for such tests were catalogued. An Australia-wide survey has been undertaken by an officer of the Division.

(*i*) *Information and Assistance to Industry and Other Organizations.*—Information has been given on such subjects as force measurement by proving rings and calibrated beams; tolerances for materials-testing machines; portable hardness-testing devices; special applications and the calibration of wire resistance strain gauges; angular speed measurement, dynamic balancing, calibration of vibrometers and accelerometers; anti-vibration isolation of galvanometers and other sensitive instruments; anti-vibration mounting of engines, compressors, and machine tools; industrial conveying by vibration; profile of camber produced by roll-grinding machines; design of machine elements; quality control; and engineering design analysis.

Assistance has been given by undertaking special test work in various instances, such as in the stroboscopic observation *in situ* of the behaviour of an alternator coupling; stroboscopic determination of the speed of a centrifuge at a hospital research laboratory and of the speed of a mill shaft for a paper manufacturer; vibration measurements as a guide to selecting the best site for sensitive instruments in the vicinity of operating plant; load-deflection tests on a diaphragm; torque-speed tests on a small motor; and pressure-frequency tests on a pneumatic vibrator.

XXIV. PHYSICS.

1. General.

The Division of Physics, as part of the National Standards Laboratory, has the statutory function of maintaining the Commonwealth standards of measurement of heat, light, and other closely related physical qualities and also the primary electrical standards.

With the continued demand from industry and from scientific research for greater precision of physical measurement, the Division, in common with standardizing laboratories in other countries, is engaged in researches designed to increase the precision of maintenance of standards and the measurement of basic physical quantities, in particular in temperature and photometry.

The Division has continued to give assistance and lvice to industrial organizations, government and niversity departments, and other Divisions of the rganization.

The Division is also engaged on researches of a more undamental nature, chiefly in solar physics and on the roperties of matter at very low temperatures.

Officers of the Division serve on committees of the tandards Association of Australia, the Australian ational Committee on Illumination, and the National ssociation of Testing Authorities, and on the Optical Munitions Technical Advisory Committee of the Department of Supply. The officer in charge of the Heat Section has been invited to attend the next meeting of the Consultative Committee on Thermometry of he Bureau International des Poids et Mesures, and has lso been appointed a member of Commission I of the nstitut International du Froid.

A leading part has been taken by the Division in rganizing regular colloquia on theoretical physics which are attended by specialists from the University of Sydney and from other Divisions of the Organization n Sydney.

2. HEAT.

The work on heat falls into two main parts: the maintenance of temperature standards, the calibration of temperature-measuring instruments and equipment, and the provision of advice and assistance to industrial and scientific bodies; and researches in the fields of low temperature physics and phase nucleation.

Work undertaken for other bodies has included the calibration of temperature-measuring equipment of all kinds, the calibration of hygrometers and viscometers, the checking of industrial pyrometric installations, and the calibration of furnaces and associated equipment used in industrial processes. Among the numerous problems on which detailed advice has been given are: the design of industrial equipment to test the refrigerative capacity of space-cooling units under various conditions of operation; the design of special furnaces and oil baths; the measurement of the temperature of sheet metal during processing; the design of a low-temperature cryostat for steel stabilization; and methods of determining the thermal properties of concrete to be used in the construction of dams by the Snowy River Authority.

Apparatus has been designed and constructed to provide improved methods for measuring the body temperature of cattle in studies of the energy balance of cattle in tropical regions. Apparatus designed and constructed in the Laboratory for the measurement of thermal conductivities has been lent to the Department of Geophysics of the Australian National University for the measurement of the thermal conductivity of rocks.

As in previous years, a course of training in temperature measurement, with particular attention to industrial pyrometry, has been given to selected persons from industry.

(*a*) *Measurement and Control of Temperature.*—(i) *International Temperature Scale*—The adoption in 1927 of the International Temperature Scale was a recognition of the importance of accurate temperature measured for industrial and scientific purposes. The accuracy required now, however, is much greater than it was in 1927; where previously thousandths of a centigrade degree were seldom significant, measurements to ten-thousandths of a degree are now of importance in certain ranges of temperature. The attainment of an accuracy of this order requires not only improvement in the realization of the Scale but the more precise definition of the Scale itself. The research on which any such revision of the definition of the Scale would be based comes mainly from the standardizing laboratories of the world, and it is expected that some of the investigations made by the Heat Section will contribute to this end. Further work has been undertaken on the more accurate realization of the present Scale, such as the construction of improved resistance thermometers, improvements in the realization of the fixed points used for the calibration of resistance thermometers and thermocouples, improvements in the equipment for the precise measurement of temperature in the optical pyrometry region, and the analysis of sources of error occurring in optical pyrometry.

Although 1,063° C. is the upper limit for the measurement of temperature on the International Temperature Scale with thermocouples and the lower limit for optical pyrometers, thermocouples are extensively used industrially in the optical pyrometer range, and vice versa. Special equipment involving a platinum black-body source has been constructed to enable the two types of instruments to be intercompared in the overlapping regions.

(ii) *Thermo-electric Effects due to Strain.*—The accuracy with which temperature can be measured with a thermocouple is usually limited by the effect of inhomogeneities in the thermocouple wires in the region of temperature gradient. An investigation of the effects of strain in producing these inhomogeneities has been made on a number of metals, including metals of high purity. These investigations may be regarded as being complementary to the measurements of Bridgman, in the United States of America, on the effects of hydrostatic pressure on thermo-electric effects, although they cover a greater temperature range. In the measurements the effects due to elastic and plastic strain have been differentiated. Some progress has been made towards a theoretical explanation of the effects observed, and a relationship has been derived between the effect of strain on the thermo-electric force and its effect on electrical resistance.

(iii) *Standardization of Thermometers.*—The officer in charge of the Heat Section recently attended a meeting of the Technical Committee of the International Standards Organization, concerned with the specification and testing of thermometers. Some work in the Laboraotry has been designed to provide a more rational system for the specification of liquid-in-glass thermometers than has been used hitherto.

(*b*) *Hygrometry.*—In studies of the theory of the measurement of humidity by means of the equilibrium temperature attained by a wet surface in a moving air stream, a knowledge is required of the emissivity of the wet surface for black-body radiation at room temperature. Such a measurement entails considerable experimental difficulty, since it is necessary to eliminate any temperature effects due to evaporation. No accurate measurements under these conditions have hitherto been made. The emissivity has been measured for water-wetted cotton, and the method is applicable to other kinds of wetted surfaces.

(*c*) *Phase Nucleation.*—The study of phase nucleation, which deals with the initiation of the new phase in processes involving change of state, is of importance in meteorology and in techniques of industrial physical chemistry. It provides also an independent approach to more basic problems concerning the structure of matter. Investigations are in progress on both vapour-liquid and liquid-solid phase nucleation.

Although the nucleation of the liquid phase in the body of the vapour has been studied theoretically, there are practically no such studies of the process of condensation on a surface. By using a treatment similar to that applicable to nucleation in the vapour, and taking account of modern ideas on the structure of crystal surfaces, derived mainly from work on crystal growth, the vapour pressures at which condensation would be expected to occur at different types of nucleation sites on the crystal surface have been calculated. It has been shown that, for contact angles appreciably greater than zero, a substantial supersaturation is necessary to initiate condensation on a perfect plane, and that the first droplets are likely to form at surface defects.

Apparatus for the investigation of the freezing of supercooled water or other liquids on clean surfaces has been constructed. Its use is awaiting completion of experiments on the growth of crystalline metal surfaces by vacuum deposition on a substrate of the same metal. This apparatus can also be used for experiments to test deductions from the theory mentioned in the preceding paragraph of condensation of liquids on solid surfaces.

It is known that hysteresis occurs in the adsorption of a substance on a solid surface when the vapour pressure is changed. A theoretical investigation has been made to determine whether purely two-dimensional considerations can successfully explain this phenomenon. It has been shown that irreversible processes are bound to be associated with the formation of a new surface phase on an imperfect solid surface, and hence hysteresis effects in adsorption processes are to be expected when two-dimensional phase transitions occur. The theory also explains the observation that the onset of such a phase change is gradual and not the sudden onset that would be expected for condensation on a perfect surface.

(*d*) *Precipitation.*—Laboratory investigations of processes connected with rain formation have been continued, the phenomena under investigation being the coalescence of water drops with mist droplets by collision, and the production of ice crystals in a supercooled cloud by "seeding" with solid carbon dioxide. A more detailed account of the investigations is given in Chapter XXVII., Section 8.

(*e*) *Low-temperature Physics, Theoretical Research.*—The significance of the low-temperature field as a proving ground for theories of the physical properties of solids is well recognized. Much of its value in this regard lies in the fact that the effects of thermal agitation, which at higher temperatures mask theoretically important phenomena, may be avoided. This is particularly so in conduction phenomena and for this reason theoretical studies have been made during the year of both electrical and thermal conductivity. Conduction phenomena in solids at low temperatures are very sensitive to crystal imperfections, and theoretical interpretation of the experimental results may give valuable information applicable to the properties of metals and solids generally.

(i) *Electrical Conductivity.*—The theory of electrical conductivity of non-superconducting metals at very low temperatures, referred to in the last Annual Report, has been considerably strengthened and extended. This theory provides an explanation for the anomalous rise in the electrical resistance of some metals with decreasing temperature. Calculations have been made of the angular distribution of scattering of the electrons responsible for the conduction. The results support the theory advanced, namely, that the anomalous effect is associated with the forward scattering of electrons by crystal imperfections. The effect of the dispersion of lattice waves on the low-temperature electrical resistances of metals has also been studied.

(ii) *Thermal Conductivity.*—Current theories of the thermal conductivity of metals fail to give satisfactory agreement with measured values at low temperatures, in respect of both the absolute magnitude of the conductivity and its dependence on temperature. Theoretical studies made in the Division have shown that the solution hitherto given for the basic equation is seriously in error and that the correct solution gives results which are in good agreement with observation thus the theory of thermal conductivity may now be regarded as being in the same satisfactory condition as the theory of normal electrical conductivity.

The theory of the thermal conductivity of semiconductors and of metals in the electrical super-conducting state is also being studied.

In dielectric solids scattering of heat waves by boundaries and lattice defects in the crystal may play an important part in determining the low-temperature thermal conductivity. Consideration has been given to these effects for diamond and artificial sapphire, and an estimate has been made of the size and concentration of the clusters of lattice defects required to explain recent experimental results on diamond.

(*f*) *Low-temperature Physics, Experimental Research.*—(i) *Helium Liquefier.*—The basic equipment for experimental low-temperature research necessarily includes a means of obtaining temperatures down to about 1° K. For this use is made of liquid helium, which has a normal boiling point of 4.2° K. The helium liquefier which has been under construction in the Laboratory for several years has now been brought into successful operation, following modifications to improve its efficiency. It has proved capable of attaining the liquefaction temperature of helium, starting at room temperature, in 1½ hr., and of producing 3.5 l./hr. of liquid helium. The unit is the first of its type to be successfully constructed outside the United States, and while operational troubles must be expected because of the exacting and unusual conditions under which it functions, steps have been taken to anticipate and minimize them as far as possible.

The liquefaction rate available makes possible the storage of liquid helium in quantities sufficient to last for several days, so that experimentation over extended periods should be practicable independently of the operation of the liquefier. Devices for the storage of liquid helium, for its transfer to experimental apparatus, and for determining levels of liquid helium in opaque vessels have been constructed.

(ii) *Thermal Conductivity and Specific Heat.*—Cryostats and associated equipment suitable for a wide range of experimental investigations at low temperatures have been set up. Initially attention is being given to the study of the thermal conductivities of solids and to the measurement of specific heats. The thermal conductivities are of significance in connexion with predictions arising out of the theoretical work referred to in the preceding section, and are also of technological importance. Specific heats are of theoretical significance in connexion with the atomic structure of substances at low temperatures and the measurement of the thermodynamic constants of materials. Measurements of the thermal conductivities of gold and of stainless steel have been made down to 54° K. and are now being extended to about 1° K. Equipment is being made for measuring the specific heats of pure metals.

(iii) *Temperature Measurement.*—As specific heat and other investigations at low temperatures are vitally dependent on accurate temperature measurement, apparatus for the realization of the hydrogen boiling point is being set up, and platinum resistance thermometers for use down to 10° K. are being constructed. Other temperature-measuring equipment set up for use at low temperatures includes gas, helium vapour-pressure, and carbon resistance thermometers.

3. LIGHT.

There has been a continued steady demand for the calibration of standard lamps, photometers, and other photometric equipment, and the Division is called on for expert advice on optics and photometry.

Problems arising from its connexion with the Standards Association of Australia have at times necessitated laboratory investigation, e.g. retro-reflective materials for road signs and protective glasses for furnace workers. Assistance has been given to the University of Sydney in the controlled lighting of insect-breeding and plant-growing rooms, and to C.S.I.R.O. and other laboratories in measurement of wool colours and of light under grasses, and in the design of new types of reflection microscopes for ultra-violet microspectrophotometry and for the metallurgical examination of metals at high temperatures.

(*a*) *Photometry.*—(i) *Photometric Standards.*—Investigations of defects in incandescent lamps used as photometric standards have been continued, and it has been found that variations of luminous intensity of 1 per cent. may occur within a change of orientation of 0.5° in commonly used standard lamps. Somewhat similar results have been obtained at the National Research Council Laboratory, Canada; and the Bureau International des Poids et Mesures, which is also concerned about the quality of photometric standards, has now arranged for the manufacture, under close supervision, of special standard lamps. Arrangements to secure lamps of this type calibrated at the Bureau International des Poids et Mesures will not only allow the Laboratory's standards to be based on those of the Bureau, but will also, it is hoped, ensure the provision of high-class lamps as standards.

(ii) *Precision Photometric Measurements.*—A physical flicker photometer is being developed for precision intercomparison of standard lamps. Light from the two sources under comparison is polarized at right angles and a colour corrected photocell, used as a null indicator, is then exposed to each source in rapid alternation through a rotating polarizer. Provision for turning the complete polarizer and comparison lamp system through a right angle permits the luminous intensity and degree of polarization to be obtained.

(iii) *Colour-temperature Measurement.*—A second flicker system has been developed to the prototype stage for colour-temperature measurement, using a standard lamp for fixed temperatures with a variable blue filter wedge for interpolation. The light from the lamp under test is passed alternately through red and blue filters, and the wedge adjusted for equal photocell output.

(iv) *Thermopile Photometer.*—A thermopile can be corrected to the eye's spectral sensitivity more readily than a photocell and may be used as a physical photometer. An instrument based on this principle is under construction for use in establishing standards for heterochromatic sources, such as fluorescent and other discharge lamps.

(v) *Colour Filter Computer.*—Colour filters of closely prescribed spectral transmissions are frequently required in a photometric laboratory, e.g., for the correction of the spectral response of photocells, for the preparation of colour limit gauges to control manufacturing processes, or in the construction of photometric instruments. Such filters normally consist of two or more coloured glasses, the calculation of whose thicknesses is usually a long and laborious process. An electrical analogue computer has been built, in which a cathode-ray oscillograph displays the spectral characteristics obtained by combining various thicknesses of two or three coloured glasses, thus permitting filters to be quickly designed.

(vi) *Spectrophotometry.*—The construction of a precision spectrophotometer, referred to in last year's Report, is well advanced. This instrument will be used in setting up spectrophotometric standards, which form the basis of all precision photometry.

(vii) *Haemoglobinometry.*—The demand by hospitals for blood samples of known haemoglobin concentration and for calibration of haemoglobinometers has further increased during the year. The present haemoglobin standard is based on the oxygen capacity of blood, but work is proceeding, in co-operation with the Red Cross Blood Transfusion Service, to express the standard in terms of iron content, as in Great Britain.

(viii) *Measurement of Wool Colour.*—At the request of the Gordon Institute of Technology, Geelong, a reliable and sensitive method, based on spectrophotometry, for the measurement of the colours of greasy and scoured wools has been developed. The results, which are expressed in the internationally recognized C.I.E. chromaticity co-ordinate system, can, in contrast to visual methods of colour assessment, be used in subsequent scientific investigations.

(ix) *Omnidirectional Photometer.* — Biological effects of light are often associated more with the energy density than with the flux across a surface, i.e illumination, that is measured by normal photometers. "Luminous energy density", however, can only be calculated, as a rule, from measurements made with ordinary photometers if the geometry of the light sources is rather simple.

To extend measurements to more general situations, an omnidirectional photometer has been developed, consisting of a pair of suitably balanced barrier-layer photocells surmounted by diffusing hemispherical shells; the resulting uniformity of response with direction of the incident light permits direct measurement of "luminous energy density". The instrument which has been constructed is of very small dimensions and will be used in the Division of Plant Industry for measurements under undisturbed grass swards.

(x) *Storage and Handling of Tar and Ammoniacal Liquor at a Gas-works.*—The Division has undertaken, at the request of one of the major gas companies, an investigation into problems arising in the storage and handling of tar and ammoniacal liquor.

It is necessary to prevent delivery to the ammonium sulphate plant of liquor containing tar in excess of a given value. Photoelectric equipment for automatic control and recording has been constructed and shows great promise.

(*b*) *Optics.*—(i) *Reflecting Microscopes.*—Reflecting microscopes developed within the Division have all been of the concentric (monocentric) type.

One of the advantages of the reflecting objective is its long working distance. One objective of focal length 0.885 inch, working distance 1.81 inches, has been made with the relatively high N.A. 0.445, and is now in use in the Division of Tribophysics for the examination of hot metal surfaces.

The main defect of the two-mirror monocentric objective is the poor contrast caused by diffraction at the obstructing convex mirror. Investigations in the Laboratory have shown that the obscuration ratio drops to tolerable limits if the primary magnification is reduced to 4X, and that, if a further stage of magnification is added, a high-power objective can be achieved, free from aberration and giving high contrast. This has been realized by the construction of an immersion objective of N.A. 0.88, having three monocentric mirrors, and a plane inclined mirror to reflect the beam out in a suitable direction. The objective is more complex mechanically and optically than the two-mirror one, but substantial advantages have been gained, and the adjustment is fairly simple.

(ii) *Optical Properties of Thin Metallic Films.*—A simple technique has been developed for making interference filters that produce the spectrum of white light. The conditions required for these filters have been examined theoretically, and the further development of filters of much higher quality, using multiple-layer films, is under way. Attention has also been devoted to the theory of multiple-layer films, and considerable simplification has already been made.

A parallel investigation has been on the reflectance and transmittance of light from thin metallic films. The results given by the electromagnetic theory have been represented graphically for varying thicknesses and compared with published experimental data. For films of continuous structure the agreement for reflection is better than generally stated, even for very thin films; for transmission the agreement holds only for relatively thick films. Theory shows that the reflectance of aluminium films deposited on glass should depend markedly on whether the light is incident through air or glass, and that in the latter case a very thin film should reduce the reflectance; these findings are in agreement with experiments.

(*c*) *Solar Physics.*—The work of the Division on solar physics is described in Chapter XXVIII, Section 2.

4. Electrical Standards.

The group of Weston standard cells on which the standard of electromotive force is based has been augmented during the year by new cells calibrated at the National Physical Laboratory of Great Britain, and an intercomparison of cells in the whole group is in progress. The present methods of intercomparison are being critically examined to devise a quicker and more accurate method. The effect of transport on the stability of cells is being investigated in co-operation with the National Physical Laboratory.

The officers who maintain the electrical standards are also responsible for the development of electronic equipment required in other investigations and researches in the Division.

XXV. ELECTROTECHNOLOGY.

1. General.

The electrical research of the Organization is undertaken within its Division of Electrotechnology. The Organization is also collaborating with the Electricity Supply Association of Australia in encouraging electrical research within the universities through its Electrical Research Board.

The Division of Electrotechnology, which forms part of the National Standards Laboratory, is responsible for maintaining the Commonwealth standards of measurement of electrical units other than the primary standards—the volt and the ohm. The Division is also investigating the properties of dielectric materials.

The work of the Division is outlined in Sections 2-7 and that of the Electrical Research Board in Section 8 of this Chapter.

Members of the Division serve on advisory and technical committees of the National Association of Testing Authorities and of the Standards Association of Australia. Technical advice on electrical and chemical problems has been given to many inquirers from industry.

Considerable attention has been given to the important problem of simplifying the operation of measuring equipment without loss of precision. Significant advances have been made in two of the main fields of electrical testing, instrument transformer testing and the calibration of capacitors.

2. Direct Current.

Monthly intercomparison of precision resistors has revealed irregularities of the order of a few parts per million, which are not significant in industrial measurements but of some research interest.

The irregularities are not confined to any particular make and are not caused by variations in storage methods.

A "build-up" resistance box has been designed for use in the calibration of precision resistors. The box contains 10 resistors, each of 10 ohms, which can be connected either in parallel or in series. It will be of direct use in calibrating a 100-ohm resistor in terms of the known value of a 1-ohm resistor.

3. Power Frequency.

Installation of the electronic control equipment for the sine-wave alternator set has now been completed. As a result of the improved stability, one observer is able to carry out accurately and expeditiously calibration work which previously required two observers.

Of great importance in an electrical standardizing laboratory is the "transfer" instrument by means of which r.m.s. alternating voltages are related to the D.C. voltage maintained with standard cells. The instrument used for this purpose at the National Standards Laboratory is an electrostatic voltmeter. It is known that this type of transfer instrument sometimes has small but significant transfer errors which are difficult to measure. The measurement has been carried out successfully by a novel method in which the amplitude of a very pure sine wave is measured by comparing its instantaneous peak value with the D.C. voltage which gives the same deflection on the transfer instrument.

Progress in instrument transformer testing has included the development of a portable voltage transformer testing set and of improved detection apparatus for use in current transformer testing. A high-gain detector amplifier with tuning continuously adjustable between 20 and 60 c/s. has been developed for general use.

Considerable improvements in stability of air-dielectric capacitors have been made by careful attention to mechanical design and by hermetic sealing of the capacitor units.

Useful information on the internal state of a metal sample can be obtained by measuring its resistivity in different directions. Assistance was given to the Division of Tribophysics in developing a technique for measuring the transverse resistivity of drawn copper-alloy wires.

4. Audio and Radio Frequency.

There has been a steady demand for precision measurements, particularly of capacitance and frequency, and developmental work is directed towards improving measuring techniques for these quantities.

(*a*) *Impedance Measurements.*—The construction of a six-dial three-terminal capacitor with a range of 1 μF. to 1 pF. has simplified considerably the measurement of capacitance. Another type of decade capacitor with a range of 1 pF. to 10^{-5} pF. is being constructed.

The development of transformers as ratio devices in A.C. bridge circuits has continued. A transformer has been produced in which the ratios of the secondary voltages differ from the turns ratios by less than one part in 10,000,000. This accuracy was achieved by using copper and "Mumetal" shields to produce a space for the secondary windings in which the leakage field from the primary is very much reduced.

The limitation to the sensitivity of A.C. bridges imposed by thermal noise has been investigated. The development of a detector giving the optimum signal-to-noise ratio and the most useful presentation is in hand.

(*b*) *Dielectric Measurements.*—A new A.C. bridge for the measurement of the dielectric properties of materials at frequencies from 5 c/s. to 150 kc/s. has en constructed. The bridge uses transformer ratios nd feedback amplifiers to give simple and quick operaon without loss of accuracy.

(c) *Frequency Measurement.*—The group of quartz ystal oscillators comprising the national standard of equency has now been in operation for some years nd is performing very satisfactorily. One oscillator as been in continuous operation since August, 1949, nd its drift rate is now only four parts in 10^{10} per ay. Two new oscillators with improved temperature ontrol and maintaining circuits have been placed in rvice, and beat counters to compare them continuously ith the other three oscillators are being constructed.

Equipment has been designed for the precise measureent of frequencies in the range 100-50,000 Mc/s. y reference to the existing low-frequency standards. he portions already completed permit some measureents to be made up to 25,000 Mc/s.

(d) *Noise Generators.*—Further investigations have een made of random-noise generators at 3,000 Mc/s. or determining the absolute sensitivity of radio eceivers. Discharge tubes filled with argon of high urity have been compared with a low temperature lack-body radiator of known output. These discharge ubes have given a stable output at a high level, correponding to radiation from a black-body source at about 1,000° K. An instrument incorporating one of these ubes has been constructed for measuring the sensitivity f receivers.

Fundamental investigations are being made of the andom noise radiated from experimental discharge ubes over a range of discharge conditions. The equivaent noise temperatures are compared with values of the mean energy of the electrons in the discharge determined experimentally by means of Langmuir probes inserted through the tube walls.

(e) *Microwave Spectroscopy.*—The microwave spectroscope has been redesigned for permanent installation and the constructional work is well advanced. The equipment has been made as flexible as possible so that the three basic systems that are used may be set up with a minimum of effort. These systems are: (a) Stark modulation which has a high sensitivity and is useful for searching for absorption lines but not for determining their true shape; (b) source modulation; and (c) straight absorption. The last two systems may be used to determine the shape of the absorption line.

The sensitivity of the straight absorption method has been greatly improved by the development of a special type of electronic cross-correlator, which has also proved valuable generally for detecting weak periodic signals in the presence of noise.

(f) *Millimetre Wavelengths.*—Apparatus is being constructed for generation and detection of radio energy at a wavelength of about 8 mm., mainly with a view to extending dielectric measurements and microwave spectroscopy to the highest available frequencies.

5. MAGNETIC MEASUREMENTS.

The steadily increasing volume of routine magnetic measurements has restricted the amount of new work undertaken in this field. The principal new development is a portable battery-operated magnetometer now nearing completion.

6. DIELECTRIC INVESTIGATIONS.

A new project of considerable interest is the study of the large enhancement of the conductivity produced in inorganic salts, minerals, and some organic compounds when they are freshly ground.

(a) *Theoretical Investigations.*—An investigation of the frequency-dependent dielectric properties of dipolar substances was carried out. The dipole-dipole interaction was accounted for statistically according to the method of Onsager, and the various relaxation times occurring in the theory were suitably distinguished. The calculations were taken to various orders of approximation and it was shown that in all cases the dielectric loss as a function of frequency could be expressed as a Debye curve.

(b) *Dielectric Properties of Mixtures.*—In previous years, the properties of mixtures of a conducting liquid and a non-conducting solid were investigated. This work has been continued with the investigation of mixtures of a conducting and a non-conducting solid. When the conducting solid is in the form of small spheres dispersed in a non-conducting base material, good agreement has been obtained between calculated and measured electrical properties. Mixtures have also been made in which the conducting material is in the form of a fine powder covering relatively large grains of the base material. The properties of these mixtures are similar to those of the liquid-solid mixtures studied earlier.

The dielectric absorption observed in these mixtures is similar to that in many commercial insulating materials and the results of this programme may have general application to such materials.

(c) *Dielectric Properties of Hydroxy-compounds.*—Further investigations have been made of the large dielectric polarization of long-chain alcohols, with particular reference to the *n*-primary alcohols with 8-16 carbon atoms. The dielectric loss factor of these materials at very low frequencies down to 0.001 c/s. has been obtained by calculation from the current flowing after the sudden application of a D.C. potential.

The effect of steric hindrance to hydrogen bonding on the dielectric properties of crystalline alcohols has been studied by making measurements with tertiary alcohols and with the secondary alcohol cholesterol in which the steric hindrance is caused by an exceptionally bulky group of atoms in the molecule.

Dielectric anisotropy has been observed in alcohols, due to orientation of the crystals. It has been investigated by a new technique, involving measurements in two directions at right angles on small square bars cut out from sample disks.

The dielectric properties of resorcinol and 4:4′-dihydroxydiphenyl have been investigated and it was found that both these compounds give quite small dielectric loss. The structures of these compounds, determined by X-ray techniques, indicate the presence of long hydrogen-bond chains. Hence it appears that all types of hydrogen-bond chains do not cause dielectric loss in solids.

(d) *Dielectric Properties of Clathrate Compounds.*—The trapping of polar molecules in the crystal lattice of quinol (clathrate compound formation) has been found to enhance the low-frequency dielectric constant which is proportional to the square of the dipole moment of the trapped molecule. The accompanying absorption is in the microwave region, with a maximum at frequencies above 2.4×10^{10} c/s. at 20° C.

(e) *X-ray Crystallography.* — Details of the mechanism of dielectric loss in hydrogen-bonded solids require precise information about the arrangement of hydroxyl groups in the material. To provide this information for secondary alcohols, the structure of 14-heptacosanol is being studied.

(f) *Measurements and Services for Industry.*—The Division was approached to investigate whether some electrical property would be a useful criterion for the estimation of the water content of tar-water mixtures. Investigation showed that loss measurements at about 1 Mc/s. could be used for this purpose.

A process for improving the performance of glass insulators by treatment with methylchlorosilane was developed it has been employed on a large scale.

7. Vacuum Electronics.

A number of the electron-beam counter tubes developed in previous years have been made. They have been used to construct a practical counter registering units, tens, hundreds, and thousands, which has been demonstrated at an exhibition of instruments.

Considerable interest has been shown in these counter tubes, particularly in the United States of America. Various claims for the counter tube have been covered by patents taken out in Australia, Great Britain, and North America.

8. Electrical Research Board.

The general objective of the Electrical Research Board is the fostering of fundamental electrical research in universities and the training of graduates in research methods. Grants are made for projects suggested by the universities.

The Board is representative of the Electricity Supply Association of Australia, the Universities, and the Organization. Financial support from member organizations of the Electricity Supply Association has enabled the Board to support investigations in most of the universities of Australia.

Stability of power supply systems is being investigated in the University of Adelaide with simulating networks and in the University of Melbourne by a model machine technique. Transients are being studied in the University of Tasmania. The protection of electrical plant against lightning has been taken up in the University of Queensland, which is being assisted in the construction of an impulse generator. A new programme has been established in the University of Western Australia on the performance of A.C. motors and their application to rural distribution systems. The study of arcs is being continued in the University of Sydney. A grant has been made for equipment required for operating a high-powered electron tube which will be used in generating radio pulses for gyro-interaction studies of the ionosphere.

XXVI. RADIOPHYSICS.

1. General.

Research on the propagation, transmission, and detection of radio waves is undertaken by the Division of Radiophysics and by the Radio Research Board. The Organization's work in this field has contributed to the advancement of basic scientific knowledge and has had wide practical application in the fields of radio communication, navigation, and meteorological physics. Extensive international collaboration has continued and the Australian contribution has been substantial. During the latter part of the year officers have been engaged in preparation for the Tenth General Assembly of the International Union of Scientific Radio (U.R.S.I.) which will meet in Sydney in August. The Chief Scientific Officer of the Radio Research Board is a Vice-president of the Union and President of its Commission on Radio Astronomy, of which the Deputy Chief of the Division of Radiophysics is Secretary.

Division of Radiophysics.—The main laboratories of the Division of Radiophysics are in the grounds of the University of Sydney. The work of the Division on radio aids to navigation is reported in Section 2 and that on the ionosphere in Section 3.

During the year important advances were made in radio astronomy. Following the discovery in the United States of America of an atomic spectral line in the radiation from the galaxy, the Division completed the first survey of these radio waves over the sky.

In the solar field, an important instrumental development was completed when a 32-aerial radio interferometer was brought into operation. This instrument, which has a higher resolution than any other radio equipment in the world, is now being used to make detailed observations of the sun.

The Division's work on radio astronomy is reported in Chapter XXVIII., Section 3.

The Division has also continued its work on the physics of rain and clouds and on the artificial production of rain. Substantial progress has been made in this work which is reported in Chapter XXVII., Sections 9-11, Section 12 of which reports its work on winds at great heights.

The Division's high-speed electronic computor was completed and is now in continuous operation. This is important as it is the only high-speed electronic computer in Australia. The Division's mathematical investigations are reported in Chapter XXX., Section 3 (*c*) and (*d*).

Radio Research Board.—The Board's investigations are mainly studies of the ionosphere, the region of the upper atmosphere responsible for nearly all long-distance radio propagation.

The Radio Research Board has continued its policy of concentrating the efforts of its staff on a few fundamental problems, and at the same time fostering and assisting complementary investigations in the universities. The Board's full-time staff has been located at the Electrical Engineering Department, University of Sydney, and at the Solar Observatory, Mount Stromlo. Approved projects have also been supported at the Universities of Queensland, Tasmania, Western Australia, and Adelaide. Some ex-members of the Board's staff are still co-operating in theoretical investigations.

During the year Dr. B. R. Rao, of Andhra University, South India, worked with the Board's Chief Scientific Officer at Canberra, as a Senior Research Student under the Colombo Plan.

The Australian Radio Propagation Committee is an advisory technical committee of the Board consisting of representatives of all Commonwealth Departments and Organizations interested in radio propagation. It has made recommendations to the Board concerning the Ionospheric Prediction Service of the Department of the Interior, and the work of the Postmaster-General's Department in establishing radio links for inter-city telephone services.

2. Radio Aids to Navigation.

The development of the Division's Microwave Navigation system has been virtually completed during the year. It has therefore been possible for the navigation group to devote increased effort to the possible application of distance-measuring techniques to the long-range navigation of aircraft, a project which was briefly mentioned in last year's Report.

(*a*) *Long-range Navigation using Distance-measuring Techniques.*—At present, the navigation of an aircraft over distances of 1,000-2,000 miles requires a trained navigator to obtain a position fix. A system giving the pilot a continuous and direct indication of the distance to his destination along a defined track would be a major operational simplification, since the aircraft's position, ground speed, and arrival time could be established with ease.

Radio waves of the length used in the short-range Distance Measuring Equipment (DME) developed by this Division do not propagate beyond the horizon and, for long distances, wavelengths reflected by the ionosphere would have to be used. Owing to the complex structure of the ionosphere, however, multiple transmission paths occur and must be identified at the receiver. Moreover, variations in the time of travel of the signals are an important consideration. It will therefore be necessary to investigate these aspects of ionospheric propagation before assessing the feasibility of the proposed system. Equipment has been developed for the transmission of pulses over a 1,100-mile path d is being installed at the Camden, New South Wales, eld Station of the Radio Research Board, and at the nospheric Prediction Service Station in Townsville, ueensland. Apart from the possible development of a w navigational aid, it is hoped that information of ndamental importance on the properties of the ionohere will result from the measurements.

(b) *Microwave Navigation.*—This system is tended for use in locations where the installation of ore elaborate navigational facilities would not be ustified. The construction of a number of engineered quipments has been completed and flight tests to valuate their performance are in progress. It is xpected that the Department of Civil Aviation will use hese models for trials under operational conditions.

Some tests of the use of the system to define the ntrance to Sydney Harbour are complete. These have hown that equipment operating at much shorter avelengths would be required for this application.

3. THE IONOSPHERE.

All long-distance radio propagation takes place hrough the ionosphere so that any new information is f practical value. The normal ionosphere is maintained in its ionized condition by radiation from the un and it therefore shows daily and seasonal variaions. These are now well known for most of the orld.

(a) *Investigations by the Radio Research Board.*—

i) *Ionospheric Winds.*—Investigation of tidal effects as already been reported. The Sydney work is yieldng new information which suggests the presence of teady winds as well as tidal motions. The main eatures so far observed are the regular movements of disturbances at horizontal speeds of the order of 5 miles a minute at a height of 200 miles and of about half hat at 60 miles. These show a seasonal change of direction from north-east in winter to south-east in summer, at the 200 miles level. In the *E* region (60 miles) the directions are different, being predominantly westerly. Some diurnal variation has been detected in the *F* region; this is being further nvestigated.

A theoretical analysis on optical lines has shown that these travelling disturbances may cause simultaneous reflections from two or three points, thus giving complex records which could easily be misinterpreted in terms of stratification in the reflecting region. This work is being supplemented by similar observations in Perth and other investigations in Brisbane.

At each of these sites (Sydney, Brisbane, and Perth) observations are made at three points, and the differences in the time of appearance of a disturbance at these points indicates its speed and directon. These are carried out at a fixed frequency; vertical soundings are carried out also at intervals, using variable frequency recorders. A new recorder of the latter type, constructed by the Radio Research Laboratory in Sydney, and now operating at Camden Field Station, makes a sweep every minute. The combination of this variable frequency system with the three-point fixed frequency system is greatly expanding our knowledge of ionospheric winds.

An auxiliary unit, designed and constructed by the Sydney group, is a receiver which listens to a broadcasting station, but responds only to the six "pips" of a time signal, thus imprinting time marks on the records.

These studies, initiated in Australia, are now being supplemented by similar observations in other countries. They are of interest in relation to geophysical theory, high altitude flight, meteorology, and the interpretation of routine ionospheric soundings.

(ii) *Electrical Conductivity.*—This work has been done in conjunction with Dr. W. G. Baker, formerly of the Board's staff, and now of Amalgamated Wireless (Australasia) Ltd. It has become clear in recent years that this conductivity, if calculated on orthodox lines, is inadequate to account for the electric currents known from magnetic considerations to flow, if these currents are generated by the "dynamo" action of air flowing radially across the Earth's magnetic field. This research has shown that the predominant conductivity over the whole Earth is the transverse (Hall) conductivity, which is some three times greater than the normal direct conductivity. When both direct and transverse conductivities are present the effective conductivity is found to be greater than either, and is some twelve times greater than the direct conductivity. This accounts for the high world-wide conductivity of the ionosphere, and vindicates the "dynamo" theory of Balfour Stewart, advanced nearly 70 years ago. Near the magnetic equator the conductivity is further enhanced by a factor of 2.4, thus accounting for the abnormally large daily magnetic variations found to occur in these regions. According to the theory these abnormal equatorial currents would flow at the 100 km. level; a recent rocket ascent carried out by the United States Navy off the coast of Peru supports this conclusion, the current-bearing layer being found to lie between 93 and 105 km. The results of this investigation are likely to have important application to the theory of ionospheric variations, and to that of ionospheric disturbed variations in magnetic storm conditions.

(iii) *Ionospheric Effects of Magnetic Storm.*—An extensive study has been made, using data from all parts of the world, of the effects of magnetic storms on the ionosphere. Such storms arise when the sun is disturbed or "spotted"; they interrupt seriously Australia's long-distance and overseas radio circuits. As a result of this study it is hoped to give the operating authorities (Overseas Telecommunications Commission, the Defence Services, &c.) detailed information regarding alternative procedures which may be put into effect in time to minimize dislocation of their operating circuits. Parallel with this study, theoretical work has continued on the mechanism by which magnetic storms influence the ionosphere. It is believed that the main features of this mechanism have been found.

(iv) *Aurorae.*—The conclusions of the Board's staff that the aurorae are produced by protons with a velocity of several thousand km./sec. is supported by the recent spectrographic data of A. B. Meinel at Yerkes (United States of America), who measured a Doppler shift (in the hydrogen line $H\alpha$) corresponding to these velocities.

It now appears reasonably certain that the ionospheric disturbances due to magnetic storms are caused by an electrostatic field spreading over the earth from the auroral zones, in the way previously proposed by the Board's staff. The observed variation in the heights and electron densities of the F_2 region of the ionosphere in all parts of the world are in quantitative agreement with this conclusion.

The theory has been advanced by the Board's staff that the observed diurnal fluctuations of the green airglow from atomic oxygen are due to the diurnal tidal rise and fall of the F_2 region. When this region is high the lifetime of the metastable state of the oxygen atom is longest and the probability of emission of the green line is greatest. This accords with the observational evidence.

Mr. C. B. Kirkpatrick, of the New South Wales University of Technology, has completed, in association with the Board's staff, three important investigations on: the trajectories of auroral particles; the form of the disturbance magnetic field during magnetic storms; and the divergence of path of the ordinary and extraordinary rays in the ionosphere.

(v) *Absorption of Radio Waves.*—Some regions of the ionosphere tend to absorb radio waves, at certain times, instead of reflecting them. An experimental programme of measurement of these absorptive properties has been commenced at Canberra.

(vi) *Deviations of Compass Needles.*—Electric currents flowing in the inosphere are responsible for the deviations and oscillations of the compass needle, which occur at certain times. Such magnetic oscillations, of period 1 second to several minutes, are now under experimental study at Canberra.

(vii) *Pressure Oscillations.*—It has long been known that rhythmic oscillations of pressure, of period several minutes, can sometimes be observed on the barograph. There is reason to believe that such oscillations may at times be communicated to the ionosphere with greatly increased amplitudes. Instruments have been set up at Canberra to record these oscillations, both at the ground and in the ionosphere. As a by-product of this investigation it has been found that the specially designed barograph is capable of showing the lunar tide in the atmosphere in a period of months. With standard barographs some years of operation are necessary before the lunar tide can be detected. The barograph designed for this work has proved to be of interest to the Long Range Weapons Organization, which has taken up its further development.

(*b*) *Investigations by the Division of Radiophysics.*—The study of radio astronomy is closely linked with that of the ionosphere. This is clearly evident in an investigation concerning the attenuation which is suffered by 15-m. cosmic radio waves on passing through the ionosphere. The attenuation is recognized through the measured intensity falling below the value obtained when ionospheric attenuation is believed to be trivial. It is found that there are regular diurnal effects which can be separated into components which appear due to different regions in the ionosphere, and irregular effects due to disturbances. Both regular and irregular effects are being studied.

A series of measurements linked in a different fashion with radio astronomy concerns the temperature of the *D* region of the ionosphere. This temperature can be measured by observing the intensity of radio waves (of frequency about 2 Mc/s.) emitted thermally. The method is analogous to the measurement of the temperature of a furnace by means of an optical pyrometer. It was first applied in radio by this Division to the measurement of the temperature of the million-degree solar corona. A series of measurements extending over a year was completed and is now being analysed.

The above method, when applied to the ionosphere, has the weakness that it requires supplementary information to locate the height of the region whose temperature is being measured. In cases where the observed temperature changes, as, for example, during a radio fade-out when it is observed to rise some tens of degrees, it is not feasible to say how much of the change is due to a change of height of the region concerned and how much to a general heating up of the region.

Exploratory observations of the echoes obtained at a similar frequency (2.28 Mc/s.) were made to see if such information could be obtained by this method. Published accounts of echoes from this part of the ionosphere are diverse, and it was uncertain whether echoes can be regularly obtained and, if so, what characteristics they show. The experimental arrangement differed from that normally employed in ionospheric measurements in that the observations were made at a site where the noise level was very low and a very sensitive receiver could be employed.

It was found that under such conditions weak, rapidly fading echoes could be regularly observed. From the observations it appears probable that the method can be used to obtain the information necessary for the interpretation of the temperature observations described above.

XXVII. METEOROLOGICAL PHYSICS.

1. General.

Research into physical phenomena occurring in the atmosphere is carried out by the Section of Meteorological Physics located at Highett, Victoria, the Division of Radiophysics, Sydney, and the Division of Physics, Sydney.

Laboratory investigations on precipitation by the Division of Physics are described in Section 8; and the work of the Division of Radiophysics on the physics of clouds and rain, artificial production of rain, and the measurement of wind velocities at high altitudes in Sections 9-12. Analyses of rainfall records made by the Section of Mathematical Statistics, Adelaide, are reported in Section 13.

Section of Meteorological Physics.—The Section studies the physical processes underlying and controlling the weather and climate. Though it is not responsible for the provision of forecasts, its studies contribute to the understanding on the basis of which forecasts must be made. The demand for meteorological information and prediction, notably from aviation and agriculture, continues to expand in scope, and emphasizes the need for basic long-term research.

Many fields of application of meteorological knowledge are not related to forecasting. The most effective use of natural resources in primary production depends on study of the very variable conditions in the lowest layers of the atmosphere and of the relations between the living unit and its environment. The design and ventilation of buildings, the weathering of materials, the siting and protection of crops, likewise require understanding of the meteorology of these layers. The possibilities of some measure of control of weather, e.g. of frost and rain, involve fundamental research into the mechanisms of the processes at work.

The work of the Section is described in Sections 2-7 of this Chapter.

The Section has continued to give advice on meteorological matters to inquirers with a wide range of interests including primary industry, building, radiocommunication, and aviation. During a recent overseas tour the Officer-in-charge gave lectures on micrometeorology and general circulation to meteorological institutions and to groups of the United States Army and Air Force.

2. General Circulation.

A better understanding of the longer-period changes in weather and abnormality of seasons can come only from a study of the physical processes controlling the general circulation of the atmosphere. Scientists in all countries are working on this problem and, since advance can come about only by international collaboration, contributions to this field must be regarded internationally. Work parallel to that on the global heat, moisture, and momentum transport, referred to in previous Annual Reports, is being intensively pursued in the United States of America and in some European countries.

Pioneer work in Australia has been accepted as offering one of the most promising lines of research in this field. The method involves the special analysis of widespread upper-air measurements but, as these have been available for only a relatively few years, progress must be slow. Studies are continuing, based on data from both hemispheres, of the interactions between the tropical and temperate circulations in the form of the large-scale transports of energy and momentum.

3. DYNAMIC METEOROLOGY.

Dynamic meteorology deals with some of the basic processes underlying day-to-day changes in the weather. These include the factors governing the formation, maintenance, and decay of the weather-producing systems (anticyclones, depressions, and waves in the pressure pattern). Problems of immediate concern to the sequences of weather in Australia include the formation of disturbances in easterly flow patterns, the distortion of flow patterns by mountains and land-sea boundaries, and the double structure of frontal disturbances affecting the southern half of the continent. The phenomena of tropical and temperate latitudes are in many respects quite distinct, and Australia in experiencing both, is faced with a wider range of problems than most countries.

4. TURBULENCE AND MICROMETEOROLOGY.

Micrometeorology is concerned with the detailed structure of wind, temperature, humidity, &c., and turbulence, and with the behaviour of these elements in the layer of air just above the ground.

The structure of all these elements reveals, among other complexities, a marked layering in that the wind, temperature, and humidity change very rapidly with height in the first few feet. The change depends strongly on time of day, becoming reversed at night, and also on such other factors as weather and type and condition of soil. These factors determine the nature of the climate in and around crops, which therefore differs greatly from that revealed by standard climatic data (which refer to four feet over a grass surface). The practical aim of micrometeorology is to examine these effects and turn them to best use for primary industry and for other applications.

The turbulent structure and associated stratification are of great significance to meteorology in a more fundamental sense, since virtually the whole energy of the atmosphere is derived from processes occurring in, and measurable in, these layers which thereby exert a profound influence on the atmosphere as a whole. But many of the details are imperfectly understood. It has therefore been desirable to concentrate first on the fundamental aspects of these processes. This policy has also been necessary in view of the lack in Australia of trained meteorologists with knowledge in this field, and the consequent need to combine research with training.

During the past year measurements of fine structure of wind (turbulence), temperature, and humidity have been made on a number of clear days and nights at the Field Station at Edithvale. The basic instrument records all these elements simultaneously and so allows transport of heat, water vapour, and momentum to be measured. This instrument has been duplicated and synchronous sets of values at two levels are yielding important new information on the laws of transfer. To give greater range into light wind conditions a photoelectric wind azimuth recorder has been incorporated, and the sensitive thermocouples are being replaced by fine platinum resistance elements to give improved reliability in the vapour-pressure record.

A symposium on "Atmospheric Turbulence in the Boundary Layer" held in Boston, United States of America, was sponsored by the United States Air Force and the Massachusetts Institute of Technology, and two officers of the Section were invited to attend. An account was given of the techniques developed and certain of the information already obtained.

Among important natural processes controlled in this manner is the evaporation from soil or natural surfaces. The work at Edithvale represents the first successful attempt to measure this quantity directly and the method developed is in principle the only one which can be applied to evaporation from any type of surface. One ultimate aim is to assess the net evaporative water loss from any region at any time. If the method proves too elaborate for this fully extensive use—its operation requires a trained physicist—its role may be that of a standard; from it attempts will be made to develop working formulae, expressed in terms of more easily measured and recorded quantities, and to check such formulae as have been previously advanced.

The problem of heat balance is closely analogous to water balance and is being investigated concurrently. An instrument developed to record the net incoming radiation (long- and short-wave combined) is in operation. Measurements of heat flow into the ground are also made.

This work has special importance in semi-arid regions, where both heat balance and water balance are critical. This was recognized when a member of the Section was appointed to represent the International Meteorological Association on the UNESCO Joint Commission for the Arid Zone.

Opportunity has been taken to study the microstructure of the larger scale disturbances: the passage of one cold front and one sea-breeze discontinuity have so far been bracketed within the period of observations. With the former the fall of temperature was as rapid as 10° F. in 8 sec.

Information on the variation of wind velocity with height near the ground over different types of terrain has been used by the R.A.A.F. Research and Development Unit in the accurate assessment of the take-off performance of new types of aircraft. Similar information and advice have been given to the Postmaster-General's Department in connexion with the design of high radio masts. The variation with height of storm gust velocity (the significant factor) is not so well known, and suitable anemometers are being developed to allow the problem to be investigated more thoroughly.

5. FROST PREVENTION.

Experiments have continued on the protection of fruit from frost by means of fans. In Australian fruit-growing districts a very large majority of frosts occur on relatively clear, still nights when the air some 50-100 feet above ground level is appreciably warmer and may be artificially brought down to the level of the fruit.

The practical feasibility of this method has already been demonstrated, and the chief object is to determine the most efficient design and arrangement of fans for orchards of a given size. This may vary from one crop or site to another, and meteorological advice on operation will always be desirable. Earlier trials provided an assessment of the degree of protection afforded by small (10 horse-power) fans with the axis vertical. Later trials have indicated that the area protected is considerably increased when the axis is inclined up to 60° from the vertical and revolves slowly about the vertical. Protection is then extended to some two or three times the original area. The main trials have been carried out in orange orchards in collaboration with officers of the Organization's Irrigation Research Station at Griffith, New South Wales.

Comparison of the results achieved at Griffith with the latest published work from the United States of America suggests that under comparable meteorological conditions the design is considerably more efficient than the American type of fan, which has a nearly horizontal axis.

The criterion above is entirely in terms of rise in air temperature. Additional benefit is gained from the movement of air, since transfer of heat from the air to the fruit is thereby enhanced. More attention is now being paid to measurement of air movement and simultaneous measurement of fruit and air temperature.

The Section has advised and assisted with similar work at other places by providing the thermometric equipment and undertaking responsibility for the observational work.

6. RADIO METEOROLOGY.

The structure of the troposphere and that layer of the upper atmosphere known as the ionosphere are both due ultimately to solar influence. For this reason, and perhaps more immediate dynamical ones, it might be expected that there would be some relationship between the behaviour of the two layers, though the mechanism of the connexion is not clear. Correlations between certain characteristics pertaining to the two layers have been reported from different parts of the world, and some of them appear to have definite prognostic value. Similar relationships have been sought in an investigation undertaken by the Section. For the Australian region (Canberra) the study has tended to confirm the existence of marked correlation over short periods (a week or so) between ionospheric F_2 critical frequency and mean sea-level pressure, but the investigation has failed to reveal any connexion between such periods of correlation and the synoptic situation.

An officer of the Section has continued to serve on a sub-committee formed to consider means of investigating the possibility of establishing radio-telephone links between capital cities. The efficiency and economic installation of such links depend on the meteorological and micrometeorological conditions.

7. OTHER INVESTIGATIONS.

(*a*) *Evaporation Survey.*—Surveys of water resources and of climate, particularly with a view to assessing the potential of under-developed areas, involve evaporation as a central element. Previous surveys have been based on measurements from water tanks, but these are recognized as being limited in application, and a field method of measurement of evaporation from natural surfaces is required. The use of grass-covered pots, under study in the Section, promised well, but a suitable method of maintaining the surface when conditions are dry has not yet been found.

(*b*) *Wind Tunnel.*—A wind tunnel designed for meteorological work, with working section 2 ft. 6 in. square, has been completed and is available for the calibration of air-flow instruments and an examination of air flow round model structures. The projected design of the oceanographic research ship, which will also be used for meteorological measurements at sea, has been tested for the distortion of air flow round its bows and found satisfactory. Airmeters have been calibrated for the Victorian Department of Mines.

(*c*) *Radiation Problems.*—Assistance and advice on miscellaneous problems involving atmospheric radiation have been given to the State Electricity Commission of Victoria and to the Victorian Railways.

8. PRECIPITATION.

Work on certain physical phenomena of relevance to studies of artificial and natural precipitation has continued.

Further experimental studies have been made on the capture cross-sections of raindrops for mist droplets relative to which they are falling. A knowledge of this parameter for various drop sizes and mist droplet sizes is of obvious importance in theories of raindrop growth by coalescence.

Any experimental investigation of this type made in the Laboratory is open to the criticism that the experimental material—the water drops and droplets—is less pure than in the natural conditions to which it is wished to apply the results. Surface contaminations of only molecular thickness on droplets may also make marked differences to the stability of the surface film (as in frothing of liquids), and it has therefore been considered necessary to carry out control experiments in which deliberate and known contamination was introduced. No effect has been detected by the addition of alcohol, oleic acid, and sodium chloride to the water. Similar control experiments have been made by applying an electric charge to the droplets, again without producing an observable effect. The measurements are now being analysed and extended to a wider range of drop and mist droplet sizes.

9. CLOUD PHYSICS.

(*a*) *Cloud Droplet Spectra.*—For rain to form in non-freezing clouds, some of the droplets must be larger than normal in order that they may grow by collision with the others. Observations have been made of the cloud droplet size distribution in cumulus clouds in which such a rain mechanism might be expected to occur. The technique has been to expose a slide coated with magnesium oxide to the droplets for a fraction of a second from an aircraft flying through the cloud. The droplets impinge on the coating and leave holes proportional in size to the droplet causing them. This technique has been very successful and detailed information on the vertical and horizontal distribution of drop sizes is now being obtained. This is an important advance in cloud physics, as such information has hitherto been unavailable.

(*b*) *Cloud Water Content.*—Measurements are also being made of the liquid water content of convective clouds. The instrument used gives a continuous record on being carried through a cloud in an aircraft. The amount of liquid water present at any level above the base of a cumulus-type cloud has been found to be markedly less than is predicted from simple theory. Other workers have suggested that this effect is due to dry air from the environment being mixed with the cloud air, causing evaporation of the droplets; this hypothesis is being investigated.

(*c*) *Air Movement and Velocity.*—A knowledge of the air-flow pattern around a cumulus cloud would give valuable information about the cloud and would determine the existence and nature of any entrainment of dry air from the environment into the cloud. Light metal foil strips which fall slowly and reflect radar signals are being used to investigate the air movement around a cloud. The foil is dispensed from an aircraft flying outside the cloud and its movement watched and accurately measured from a ground radar equipment. Initial experience of the technique shows promise and a series of measurements is planned.

(*d*) *Cloud Temperature.*—The measurement of cloud temperature is a difficult problem which must be solved if the causes of the formation of a cloud are to be understood. A thermometer element exposed to the cloud becomes moist and reads wet-bulb temperature. Experiments are being made with a "vortex thermometer" of the type developed by Vonnegut in the United States of America, in which a spiralling action of the airstream is used to remove water from the centre of a vortex tube in which the temperature-sensitive element is placed. The instrument is fitted to an aircraft and used in conjunction with other equipment in cloud studies.

10. RAIN PHYSICS.

(*a*) *Airborne Observations of Rain Clouds.*—An aircraft fitted with a 10-cm. radar set and other equipment for measuring meteorological phenomena has been used to observe naturally raining clouds within about 100 miles of Sydney. The study of rain clouds which do not rise above the freezing level and which consist solely of water droplets has been continued. These clouds are found frequently over the sea or relatively near the st, though sufficient data have not yet been collected to indicate whether non-freezing rain is solely a coastal phenomenon.

(b) *Ground Radar Observations.*—A detailed study of clouds by ground radar is limited to the vicinity of the radar's point of installation. Such a radar can be operated on every occasion that rain is near, and has enabled a survey to be made over a period of twelve months of the rainstorms occurring in and around Sydney. This analysis shows that 85 per cent. of the rain comes from clouds in which ice crystals occurring above freezing level play a major role, and 15 per cent. comes from clouds in which only water droplets are present. The use of lapse-time photography of the radar screen during a rainstorm enables a speeded-up picture to be shown of the appearance and growth of precipitation elements. This ensures a better appreciation of the phenomena than can be obtained from isolated observations.

(c) *Raindrop Sonde.*—Experiments in which a lloon-borne instrument was used to obtain information about the vertical structure of raindrop size stribution have been discontinued. The instrument uld be used only under conditions of very steady rain, hich has proved a disadvantage. It is not yet known hether other methods will prove more satisfactory. he results obtained with the instrument have, however, ven measurements of the rate of growth of a raindrop n falling through stratus clouds, which may prove of alue.

(d) *Airborne Raindrop Microphone.*—In order to void the limitations of the balloon-borne instrument, a pecial microphone has been installed in the nose of the adar-equipped aircraft, in a position where the wind oise is small, and is being used to measure the raindrop ize distribution. In raining clouds the raindrops triking the microphone diaphragm produce an impulse n the screen of a cathode-ray tube which is photographed on a continuously moving film. The amplitude f the impulses, which is a function of the raindrop size, s later measured, enabling a study to be made of the ize of raindrops at any position in the rainstorm.

(e) *Laboratory Experiments on Reflection from Water Drops and Ice Particles.*—The ability of radar o depict a rainstorm depends on the scattering of lectromagnetic waves by the raindrops or ice particles within the storm. A detailed knowledge of the way in which the scattering varies with particle size and shape is therefore important. In association with theoretical work an experimental study has been completed of the increase in reflection from an ice particle as it begins to melt.

(f) *Raindrop Spectrograph.*—An instrument which spreads out the raindrops into their different sizes before they fall on to a moving sheet of paper, where they leave a permanent stain, has been in use for a considerable part of the year. The variation in drop size distribution at ground level throughout a shower has been studied in conjunction with radar observations of the same storm. No correlation has been found between the type of drop distribution and the radar echo.

11. ARTIFICIAL RAIN FORMATION.

The effects produced by treating natural clouds with various substances are still under investigation. Conclusive results can be obtained on single clouds, but scientific control of large-scale seeding operations is difficult because of the natural variations in rainfall. The economic effectiveness of any process cannot, therefore, be properly assessed without a very long period of test, possibly several years.

(a) *Dry Ice.*—Dry ice was the first substance to be used successfully in rain-making experiments and its method of operation and the requirements for its success are now fairly well understood. The cloud conditions within a few hundred miles of Sydney are such that the number of opportunities for successful rainmaking by the use of dry ice is limited to well under an average of one day per week. This fact, combined with the cost of the aircraft that must be used to dispense the dry ice into the top of the cloud, indicates that the economic possibilities are small for rain-making in the Sydney area. There may, however, be certain areas where cloud conditions are more suitable or where a small increase of rain at a certain time of the year is of major importance.

(b) *Silver Iodide.*—The effect of silver iodide is similar to that of dry ice when introduced into a cloud in the form of a smoke of small crystals. It is also effective only in supercooled clouds. Some spectacular claims have been made for it in the United States of America, where it is used over large areas by burning it in smoke generators on the ground and relying upon natural convection to carry it up into suitable clouds. However, there is considerable doubt whether the reported increases in rainfall are due to the action of the silver iodide or to climatological factors.

A smoke generator was operated at Hay in the Riverina district of New South Wales for the three months commencing July, 1951. An analysis of the records made by the Weather Bureau rain-gauge observers within 100 miles or so of Hay is being made, based on a comparison of the rainfall downwind from the generator with that upwind, corrections being made for the natural variation of rainfall from place to place. Although the analysis is not yet complete, it can be stated that the rainfall in the downwind sector was greater than that upwind, but that the magnitude of the increase was not sufficiently large to say whether it was due to the action of the silver iodide or to natural causes.

(c) *Water Spray.*—Another method of artificially producing rain, which originated in this Division, is to spray small water droplets into the base of a suitable cloud. The droplets grow by collision with the cloud droplets in their path as they rise in the updraught that produced the cloud and, after growing to a sufficient size, fall out as rain. A few more trials of this method have been made and moderate success achieved.

(d) *Large Condensation Nuclei.*—Instead of seeding non-freezing clouds with water droplets as indicated above, a similar result might be achieved if large hygroscopic nuclei were placed in the saturated air at the base of the cloud where they would grow into droplets by the condensation of water vapour on them. Provided a large enough droplet can be formed in this way, it will subsequently grow by collision with the natural cloud droplets in its path and eventually fall out of the cloud as a raindrop. Experiments are being performed in an effort to produce such nuclei upon which water will condense. The use of nuclei in place of water droplets would have better economic prospects since the quantity of material that needs to be dispensed from the seeding aircraft would be much less for the same end result.

12. WIND MEASUREMENTS AT GREAT HEIGHTS.

Very few observations have yet been made in the southern hemisphere of wind velocities at altitudes above 30,000 feet, where many modern civil and military aircraft expect to operate. The Division commenced systematic observations in August, 1951, and intends to continue them daily for twelve months. A study is being made of the variation of wind velocity at high altitudes in different seasons and the diurnal variation is also to be investigated.

The method of observation is to use radar to track special reflecting balloons released from the Laboratory. Radar allows measurements to be made irrespective of weather conditions. Exceedingly high winds of over 150 knots have been observed occasionally at 40,000 feet, where the prevailing wind is westerly and is usually about 60 knots.

13. Analysis of Rainfall Records.

(*a*) *Secular Variation of Rainfall at Adelaide and Perth.*—These stations are representative of the winter rainfall zones of South Australia and Western Australia respectively.

The previous analysis of Adelaide records for 1839-1933 has been extended to 1950 and the Perth records for 1880-1948 have been similarly analysed. The results show an interesting contrast. For Adelaide the previous finding of an oscillation in incidence and duration of winter rains with a period of 22 years and an amplitude of approximately 30 days has been confirmed with greater precision. A second superimposed trend has been found, no doubt also periodic, with a period of not less than 225 years—the principal manifestation being an advancement of spring rains by as much as three weeks. The Perth analysis has found two superimposed changes in quantity of precipitation—a short-term, possibly periodic, movement with peaks at 1880 and 1920, and a long-term trend yielding an increase in annual rainfall of about 5 inches since 1880. There has also been a gradual reduction in the length of the season, with the spring rains ending about two weeks earlier than they did twenty years ago.

(*b*) *Expectation of Monthly Rainfall in South Australia.*—Pastoral regions have been partitioned into three zones: summer rainfall, winter rainfall, and transitional, and the probabilities determined that the season will open and terminate in specified months and the period of excess of precipitation over evapo-transpiration will be of specified length.

(*c*) *Correlation of Monthly Rainfall.*—In last year's Report, reference was made to the problem of predicting rainfall at any given station from values of the same variate at neighbouring stations. The scope of this work has now been extended to embrace much larger areas, to determine how the correlation is related to inter-station distance, and to find the axes of maximum and minimum correlation whenever the relation between correlation and inter-station distance is not the same in every direction through a specified point.

XXVIII. EXTRATERRESTRIAL PHYSICS.

1. General.

The study of solar radiation by the Division of Physics is described in Section 2 of this Chapter. The work of the Division of Radiophysics in the field of radio astronomy is described in Section 3. The studies of the ionosphere reported in Chapter XXVI., Section 3, are related to extraterrestrial research.

2. Visible and Ultraviolet Solar Radiation.

In continuation of the work described in last year's Report, the Division of Physics is studying the emission of radiation from hot atmospheres, such as exist on the Sun, and is making observations on solar prominences and chromospheric flares.

(*a*) *Emission of Radiation from Hot Atmospheres.*—Since the recent discovery of high temperatures in the solar corona, it has been recognized that the Sun's outer atmosphere emits radiation mainly as a result of electron collision processes rather than as a result of re-emission of radiation after absorption. Theoretical studies of the emission of radiation due to these collision processes are being made. Calculations of the visible and ultraviolet radiations emitted by a wide variety of hot hydrogen atmospheres referred to i last year's Report have been completed, and have bee extended to one case of a mixed atmosphere of hydrogen and helium. Preliminary studies have also bee made on radiation by calcium, but further progres depends on data on rates of collision processes o which calculations have been commenced.

(*b*) *Spectroheliograph Observations of the Sun.*—A spectroheliograph, built and erected at the Laboratory, has been brought into operation during the yea for the study of solar prominences by cinematography The instrument consists of a horizontal 5-in. telescop automatically controlled by an electronic guider an fitted with a Lyot-type monochromatic filter passin a spectral band, 6 Å in effective width, centred on th hydrogen red spectral line. Prominences are photographed at 0.5-min. intervals by time-lapse cinematography.

With this filter those prominences which projec radially beyond the Sun's disk can be observed, but t observe prominences and other disturbances on th solar disk a filter transmitting a much narrowe spectral band is necessary. Such a filter is expected t be available shortly.

(*c*) *Sky Photometer.*—As the skies in Sydney ar not clear enough for good spectroheliograph observations, a sky photometer has been built and observations of the sky brightness near the Sun have been commenced in order to find a more suitable site where scattered sunlight in the atmosphere is less serious in obscuring the solar phenomena being studied.

3. Radio Astronomy.

The usual method of observing the Sun or the Moon or the myriads of other astronomical bodies is by means of the light which they emit. It is now possible to make similar observations by means of radio waves and the Radiophysics Laboratory has taken an important part in the development of this new science. Observations have been made of the radio waves emitted by the Sun, the Moon, and the Milky Way. These observations are contributing important new facts to our knowledge of the universe.

An outstanding development in radio astronomy took place this year with the discovery of an atomic spectral line in the Galaxy. The original discovery was made in the United States of America and was confirmed within a few months by work in Holland and in this Laboratory. This work was followed here by the first survey of the distribution of these radio waves over the sky.

(*a*) *Cosmic Radio Waves.*—(i) *The Atomic Hydrogen Spectral Line.*—We tend to think of the Galaxy as a vast conglomerate of stars because, when we look at the Milky Way, it is the stars that we see. But the space between the stars is not a complete vacuum. It includes extensive gas clouds and tiny solid particles. The main constituent is gaseous hydrogen and, except that in the vicinity of exceptionally hot stars there are a few regions which are caused to glow by the light of these stars, this hydrogen is completely invisible optically. It is believed that this invisible material comprises something like one-half of the total mass in the Galaxy. The atomic spectral line which has been discovered is one from interstellar hydrogen and provides for the first time a method of observing this very important constituent of our universe. The survey of distribution of the brightness of this line over the sky has shown that the radiation is concentrated in a narrow band near the plane of the Milky Way. It follows that interstellar hydrogen in the Galaxy is concentrated near this plane.

A further point of interest is that the discovery of this line provides radio astronomers for the first time with a means for measuring velocities of approach or ecession of the sources of radiation they observe. It as been found from the results of the survey that the louds of interstellar hydrogen move at random among hemselves with velocities of the order of 10 km./sec. n addition to these random movements there are great treaming movements. The most interesting of these s that associated with galactic rotation. The Galaxy otates in the plane of the Milky Way in a manner ather similar to that in which the planets rotate round the Sun. In both cases the velocities of the outer members are less than those of the inner ones. As a result, the stars in certain distant parts of the Galaxy tend to approach us, in others to recede. A similar phenomenon has been established for interstellar hydrogen from the results of the survey.

If, as seems likely, the stars and interstellar matter in a particular region in the Galaxy move together, then measurements of velocity of a mass of interstellar matter can be used to locate it. This concept has been applied to the measurements of velocity and it appears that in a region extending over a quadrant of the sky the interstellar matter is concentrated in two vast elongated masses which may well delineate spiral arms of the Galaxy.

The results on which these conclusions are based were essentially exploratory ones obtained with improvised equipment. There is a wealth of information to be gained from more detailed and precise observations and new equipment is being constructed to extend this work.

(ii) *Radio Stars or Radio Nebulae.*—In addition to the radiation from interstellar hydrogen atoms just discussed, radiation from cosmic sources is observed over a wide range of radio frequencies. Some of this originates in small sources which have been termed "radio stars". The nature of these sources is not yet known. One definite conclusion is that they are not simply the bright optical stars. Few of them agree in position with any identifiable optical object, and the amount of radio-frequency radiation emitted by one is many millions of times greater than that emitted by the Sun, which we may consider as an ordinary star.

Two new facts concerning radio stars have been established in the Laboratory over the past year. The first is derived from statistical arguments. It is concluded that there are two classes of radio stars. The first class consists of rare objects distributed thinly through the Galaxy. These objects must lie at distances of tens of thousands of light years from us and must be enormously powerful. Because the Galaxy is a flattened structure they appear concentrated near the Milky Way. The second class is distributed at random in direction and space. They could be relatively less powerful emitters distributed among the nearer stars. But it is more likely that they are even more powerful emitters in galaxies external to our own. If so, they lie at distances of millions and tens of millions of light years.

The direct test of the nature of radio stars is their identification with optical objects. Some tentative identifications were made in this Laboratory some years ago. One radio star coincided with the Crab Nebula, the remains of a supernova which exploded a thousand years ago; the other, with external galaxies. These identifications have now been confirmed by more accurate measurements of positions and several new ones have been suggested. The next step is an optical study of the objects in the hope of recognizing some peculiarities common to this type of star. Astronomers at Mount Palomar are now engaged in such a study using the great 200-in. telescope and the 48-in. Schmidt. The indications are that most interesting results are likely to emerge.

The second new fact established is that some radio stars have angular diameters of up to a degree. Previously, they were thought to be point sources. It would be more correct to call the extended ones "radio nebulae", not radio stars. Previous techniques failed to recognize the existence of a radio star if its diameter exceeded a few degrees and were unable to measure its diameter if this were less than about one-fifth of a degree. New equipment capable of recognizing larger ones has been constructed, and a number of sources several degrees in diameter have been discovered. At the same time, other equipment has been developed which should be capable of measuring the diameters of radio stars down to sizes ten or a hundred times less than the previous limit.

(*b*) *Radio Waves from the Sun.*—One aspect of the study of solar radio waves requires an aerial with a very high angular resolution, so that the detailed distribution of radio brightness over the solar disk may be observed. This year equipment which probably has a higher resolution than any radio equipment ever before constructed began operation. The aerial consists of a row of 32 6-ft. diameter parabolic aerials which are extended over a line 700 feet. long. It operates at a wavelength of 21 cm. so that the base line is about 1,000 wavelengths long and the resulting "beamwidth" of the aerial is only 3 minutes of arc. The records obtained with this equipment show numerous "bright" patches on the solar disk which move across the disk with rotation of the Sun and also slowly change. When the equipment has run for some time it should provide a very complete picture of the nature of these "bright" areas and of the background.

Another important project is the determination of the spectra of bursts and outbursts of solar radio waves in the much longer wavelength range between 1 and 7 m. Equipment for this purpose is partially completed and observations are being taken over a part of the wavelength range.

While equipments such as those described yield more spectacular results, a great deal of information comes from simple, but regular measurements of intensity on different wavelengths. Routine recording of solar radio wave intensity is carried out in this Laboratory on wavelengths of 3, 10, 25, 50, 300 and 500 cm. This is part of a world-wide scheme for recording solar activity and the results are published by the International Astronomical Union. These results from the various stations distributed over the world are now forwarded to this Laboratory for editing prior to publication.

XXIX. ATOMIC PHYSICS.

1. General.

The Organization is co-operating with the Physics Department of the University of Melbourne in a programme of research on nuclear physics (Section 2 (*a*)–(*c*)) and cosmic rays (Section 3 (*a*)).

Work on tracer elements has been re-organized and is now being carried out by a Section of the Organization, which is located in the Chemistry School of the University of Melbourne. This work is reported in Section 4.

Co-operative investigations on cosmic rays are also undertaken by the University of Tasmania under the direction of Professor A. L. McAulay (Section 3 (*b*)).

2. Nuclear Physics.

(*a*) *Equipment.*—The main activities of the Section centre around the three particle accelerators and the cosmic ray spectrometer. The 750 kV. high-current electrostatic generator has been put into continuous operation. The 14 MeV electron synchrotron has been moved to a site below ground level to protect adjacent laboratories from high intensity X-radiation. Thick barriers of sand encased by brick walls provide improved protection for the persons operating the synchrotron. This machine is now fully operational. The main insulating column of the 1 MeV. accelerator has been replaced with a high-grade bakelite tube from the United Kingdom and the accelerator tube has been redesigned and rebuilt. Developmental work in the early part of 1952 has resulted in an improved output and increased reliability of operation. The beam is stabilized in energy to within ± 3 keV. up to the maximum voltage. An important addition to the facilities of the Laboratory has been the construction of a ten-channel pulse analyser.

(*b*) *Angular Distribution Experiments*.—(i) 1 *MeV. Electrostatic Generator*.—A study is being made of the energies and angular distribution of the product particles in the $Li^7(d, \alpha)He^5$ and $Li^7(d, \alpha, n)He^4$ alternative reactions. In the present experiments the incident deuteron beam is introduced into the expansion chamber through a very thin mica window (stopping power 4 mm. air) where it falls on a thin target of lithium mounted in the centre of the chamber. With this technique range and direction identify the two reactions, the first reaction being clearly separated by nearly opposite tracks of unequal length which radiate from a point in the target.

A fully automatic chamber is operating and photographs are being accumulated for statistical studies.

(ii) 750 *kV. Electrostatic Generator*.—The series of experiments carried out in this Laboratory in recent years on the angular distributon of α-particles from the $Li^7(p, \alpha)He^4$ reaction has been concluded with an investigation of the angular distribution for incident protons with energies below 300 keV. Again nuclear emulsions were used to record the α-particles. The results of this experiment have confirmed the theoretical prediction that $A(E)$ should fall to negative values at low proton energies.

In another investigation the angular distributions of the γ-radiations emitted in various nuclear reactions is being studied with a view to obtaining information on angular momenta and parities of energy levels of light nuclei. The γ-radiation is detected with a scintillation counter consisting of a thallium-activated sodium iodide crystal, embedded in a perspex container, used in conjunction with an E.M.I. type 5311 photo-multiplier tube. The pulses produced have been found to be nearly proportional to the energy of the γ-ray quanta incident on the crystal. Thus pulse height analysis resolves γ-radiation of different energies. While the resolution obtained is not high, particularly for large γ-ray energies, yet it is considered sufficient to distinguish the components of many complex radiations. The high efficiency of the scintillation detector employed enables weak radiations to be investigated with good statistical accuracy.

Another investigation is concerned with the range and angular distributions of neutrons produced in the reaction $Be^9(d,n)B^{10}$. In this experiment Ilford C2 plates, 50μ emulsion thickness, were vacuum dried and placed at 30° intervals around a thick target of metallic beryllium which was then bombarded with 600 kV. deuterons. The range distribution of the proton recoil tracks, which have their whole length in the emulsion and whose initial direction makes an angle of less than 5° with the incident neutron beam, is being determined using two microscopes having different magnifications. The first microscope is used for the shorter tracks (energy < 3 MeV.) and the second for the longer tracks (energy > 2–5 MeV.). Preliminary results confirm the report by Ajzenburg that the energy level in the B^{10} nucleus in the region of 2 MeV. is a doublet. There appears also to be evidence for the existence of a further level in the region of 2.9 MeV. Measurements have been made at three angles, 0, 90, and 150° in laboratory co-ordinates, and these reveal marked differences in the angular distributions for the various groups.

(iii) *Electron Synchrotron*.—From July, 1951, until November, the work on the 14 MeV. synchrotron was mainly of a developmental nature, aimed at increasing the γ-ray output of the machine, as this was too low to make an experiment on the photodisintegration of the deuteron (using deuterium gas in a Wilson cloud chamber as the target for the γ-rays) practicable.

Careful measurements revealed that the central pole gap separation had increased by 0.040 inch (sufficient to destroy good operation) and that a record of this quantity as a function of time is desirable. Also an unbalance was discovered between the exciting currents around the top and bottom poles and correcting this gave good operation.

With a high γ-ray output from the machine, an experiment was performed with Geiger counters made of copper, to check the energy calibration of the synchrotron by measuring the γ-neutron threshold of Cu^{63}, which is accurately known. The angular distribution of the γ-ray beam was also checked using silver Geiger counters.

In January, after these experiments were completed, it was decided to move the synchrotron into a basement room. By the time the basement had been prepared and the equipment installed, two months had elapsed. During April, an improvement in γ-ray output was obtained, partly due to a decrease in pressure in the vacuum system (outgassing) and partly due to our recovery of best operating conditions, since some of the parameters were altered in transit to the basement.

At present, work is directed to operating a Wilson cloud chamber in conjunction with the synchrotron, and to the best conditions for photography. A paper has been published, describing the method by which the cloud chamber controls the output of the synchrotron. The early photographs of photo-proton tracks are satisfactory.

(*c*) *Scattering Experiments*.—(i) *Scattering of Positrons and Electrons in Gold*.—When a beam of electrons impinges in a scatterer, a certain angular distribution of the scattered particles is observed. The Dirac theory of the electron predicts that a similar beam of positrons similarly scattered will give rise to a considerably different angular distribution.

The experiment is designed to verify this for the case of 1 MeV. particles scattered by gold. Since positrons are only obtainable from radio-active sources, a β-spectrometer is used to provide a mono-energetic beam of either positrons or electrons. The only positron source which emits particles of a suitable energy, and which also has a half-life long enough to make its importation worth while, is Co^{56}. Unfortunately, this isotope is also a source of strong γ-radiation, and so the main problem in the experiment is to obtain a workable ratio of count rate to background. To achieve this, a suitable coincidence arrangement has been devised to detect the scattered particles.

Preliminary runs have yielded useful results, although the position sources available to date have not been of sufficient strength. A new source is on order from Washington, United States of America.

(ii) *Elastic Scattering of Protons by Deuterium and Deuterons by Hydrogen*.—This investigation by K. B. Mather is a continuation of work commenced in the United States of America. A photographic scattering chamber, constructed at Washington University, St. Louis, was used to study the elastic scattering of 5.1 MeV. protons by deuterium and 10.2 MeV. deuterons y hydrogen, these being the same process in the centre f mass system. The scanning of these plates has now een completed. Differential scattering cross sections were obtained from 16.4 to 172.9° and comparison made with the theoretical angular distribution of Buckingham, Hubbard, and Massey, based on a symmetrical exchange force. Agreement is close at this nergy favouring exchange rather than ordinary forces. However, at higher energies both *p-d* and *n-d* data are not represented satisfactorily by the BHM theory. This work has been sent to the *Physical Review* for publication.

3. COSMIC RAYS.

(*a*) *Cosmic Ray Spectrometer.*—Experiments on the measurement of the momentum and ionization of charged cosmic ray particles have been continued with the spectrometer.

The main project this year has been an investigation of the momentum-specific ionization relation for the meson component. A proportional counter, filled to atmospheric pressure with a mixture of argon and ethylene, was placed in the path of mesons traversing the spectrometer. The voltage pulse obtained gave a measure of the energy which was appearing as ionization in the gas of the counter. The momentum of each meson was determined in the usual manner by deflection in the magnetic field of the spectrometer.

Due to the long periods of continuous operation involved in these experiments it was found necessary to redesign the ionization-recording equipment to obtain better long-term stability.

Measurements have been made on 3,971 tracks in the momentum range $2.4\times10^{8}-1.5\times10^{10}$ eV./c. (field 1,900 gauss) and 2,579 tracks in the range $1.3\times10^{9}-5.3\times10^{10}$ eV./c. (13,500 gauss). In each case the results were divided into a number of momentum intervals and the most probable ionization calculated for each interval. When these values of the ionization were plotted against the momentum, the form of the curve obtained agreed very well with that calculated from the theoretical relations. In order to obtain an absolute value of the specific ionization, the proportional counter was calibrated with the fluorescence X-rays from various elements. In view of the approximations involved in the theory when applied to absorbers of relatively high atomic number, such as argon, the agreement of 10 per cent. was considered satisfactory.

In addition to this work further measurements have been taken on the momentum distribution and +/— ratio of cosmic ray mesons incident at various zenith angles to the east.

(*b*) *Cosmic Ray Laboratory, University of Tasmania.*—Experiments on the azimuthal variation of cosmic rays at Hobart have been continued at the University of Tasmania. Comparison of the east-west asymmetry at Hobart with that measured at Macquarie Island by the Australian National Antarctic Research Expedition shows that the asymmetry may be adequately accounted for in terms of the deflection of mesons in the earth's magnetic field. In conjunction with the Australian National Antarctic Research Expedition, improvements to the previous theory have been effected.

A north-south asymmetry has also been observed at Hobart with the excess from the north, its magnitude at 30° zenith angle being about 0.5 per cent. with 12 cm. of lead absorber. This is about half the value of the east-west asymmetry at the same zenith angle and with the same absorber. An explanation has been proposed also in terms of the deflection of mesons in the earth's field. At Hobart, the magnetic zenith is about 18° N. of the zenith so that particles arriving from the north travel more nearly along the lines of force than particles arriving from the south at the same zenith angle. Hence, the particles from the north are deflected less than those from the south. Satisfactory quantitative agreement between this theory and the measured north-south asymmetry has been obtained. Measurements at intermediate azimuths are being made.

The data from the experiments have been examined for variation due to meteorological changes. It appears likely that the barometer coefficient increases with zenith angle.

4. TRACER ELEMENTS INVESTIGATIONS.

Towards the end of 1951 new arrangements were made for tracer elements work; staff of the Organization previously working in the Commonwealth X-ray and Radium Laboratory were transferred to a Tracer Elements Investigations Section. This group is available to assist other Divisions and Sections, and University and other laboratories, with problems associated with the use of isotopes in non-medical research, to synthesize chemical compounds isotopically labelled, and to carry out independent research.

Through the courtesy of Professor Hartung, temporary laboratory and office space has been provided in the Chemistry School, University of Melbourne. Part of this space has been air-conditioned and equipped as a counting room, allowing radioactive assay work to be kept separate from chemical work.

(*a*) *Radiochemical Synthesis and Processing.*—A simple high-vacuum system for handling small amounts of radioactive gases and vapours is operating on a routine basis. Many simple organic reactions, such as Grignard reactions and lithium aluminium hydride reductions, can now be performed on a millimole scale with this apparatus.

Suitable methods of synthesizing labelled compounds that are not readily available overseas are being developed. "Methoxone" (2-methyl-4-chlorophenoxyacetic acid), glycerol, oxalic acid, α-ketoglutaric acid, and various ketones, α-diketones, and α-glycols are all required labelled with C^{14}. A long-chain mercapto-acid labelled with S^{35} is also needed.

A combustion train has been set up for the dry oxidation of organic material containing C^{14} to barium carbonate, and for its subsequent mounting for assay as "infinitely" thick samples. This is an alternative to the wet oxidation procedure with the Van Slyke-Folch reagent.

Radioactive sources for various users have been prepared on suitable mounts when needed.

(*b*) *Isotope Effect on Chemical Reaction Rates.*—The C^{14}-isotope effect in the Cannizzaro reaction of C^{14}-formaldehyde has been studied in conjunction with Dr. G. M. Harris, of the University of Melbourne. For this reaction the rate constant for C^{14} molecules was found to be about 6 per cent. less than for C^{12} molecules. An effect of similar magnitude has also been found for the reaction of C^{14}-formaldehyde with dimedone. Equations have been derived which express the specific activities of an isotopic reactant and product at any stage of a reaction involving an isotope effect.

Other well-known organic reactions are being studied to see if they exhibit C^{14} isotope effects. The latter have more than a theoretical significance since they may have an important bearing on the accuracy of a tracer study.

(*c*) *Pilot and Assay Experiments.*—Further assistance has been given to the Irrigation Research Station, Griffith, with the assay of radiosodium, Na^{22}, samples in the study of salt movement in irrigated soil. For this work, and for the assay of weekly radioactive powdered mineral samples, an annular lead castle has been constructed. This method of assay is very convenient for γ-ray emitters, because little time is spent on sample preparation. The apparatus is at present being used by the Ore-Dressing Laboratory for the assay of monazite-containing mineral fractions.

The penetrating nature of γ-rays enables suitable radioactive sources to be detected by a Geiger counter or other means, through quite large thicknesses of interposed material. Many descriptions have been published of different practical applications of this radioactive method of marking hidden objects, and it is evident that a difficulty often encountered is to obtain an accurate directional location of the hidden source, while keeping its radioactive strength at a reasonably safe (and economical) figure. This problem is being studied for the case of buried sources through moderate thicknesses of soil.

Radiophosphorus, P^{32}, has been applied as a tracer in the Central Experimental Workshops, to test the efficiency of the centrifugal drying of washed dried fruit; it has provided a very sensitive means of measuring the minute amount of water retained on the surface of the fruit.

(*d*) *Information.*—Information on equipment and methods for radioactive tracer work, and on various applications, has been supplied to local and overseas workers. Most of the stock of lead castles made in the Central Experimental Workshops has now been disposed of, and negotiations are being made for a commercial firm to undertake their further manufacture to C.S.I.R.O. designs.

During July, 1951, Dr. T. H. Oddie made a brief visit to England to attend an Isotopes Techniques Conference at Oxford, organized by the Atomic Energy Research Establishment. This conference provided a very full programme of papers covering applications of isotopes in scientific, medical, and industrial fields.

XXX. MATHEMATICS.

1. General.

In Section 2 of this Chapter are described investigations by the Section of Mathematical Statistics on methods of analysis applicable to various processes and experimental studies.

Computing equipment is described which has been developed by the Section of Mathematical Instruments (Section 3 (*a*) and (*b*)), by the Division of Radiophysics (Section 3 (*c*) and (*d*)), and by the Division of Electrotechnology (Section 3 (*e*)).

Section of Mathematical Statistics.—This Section, with headquarters in Adelaide, is responsible for providing mathematical assistance in the planning of experiments and the interpretation of results. Much of the Section's work is reported in other chapters—Chapter III., Section 27; Chapter VII., Section 13 (*c*); and Chapter XXVII., Section 13.

During the past twelve months, the Section's activities have broadened considerably, principally in the development of its own research programme, as a direct result of an increase in the number of trained staff. At the present time its major function remains, however, the provision of assistance in the Organization's diverse programme. This is most efficiently performed by attaching officers of the Mathematical Statistics staff to certain Divisions or at appropriate centres (six now in all—at Canberra, Melbourne (2), Sydney (2), and Perth) in addition to head-quarters at Adelaide, but carries with it the disadvantages of decentralization.

Valuable contact is maintained with Commonwealth and State departments, universities, and individual workers, requests for assistance being of greater magnitude and more numerous than at any time in the past.

Regular courses of lectures are provided within university curricula, and a great deal of time is necessarily devoted to the training of staff preparatory to their posting to a centre. Guidance in the training of officers of other organizations has also been undertaken on several occasions.

Section of Mathematical Instruments.—This Section is located in the Electrical Engineering Department of the University of Sydney and has continued investigations on the development and use of automatic calculating machines and control devices.

A major activity of the Section was the organizing of a conference on automatic computing which was held in Sydney in August, 1951. Members of the Radiophysics Division's computing group took an active part in the proceedings of the conference. The organizers were fortunate in being able to arrange for the conference to take place during the visit to Australia of Professor D. R. Hartree, F.R.S., Plummer Professor of Mathematical Physics at the University of Cambridge. Professor Hartree read a number of papers at the conference and made stimulating contributions to many of the discussions. The conference was attended by about 200 visitors from many parts of Australia.

The Section's research activities have continued to embrace both analogue instruments and components of digital machines.

2. Analysis.

(*a*) *Use of Scores for the Analysis of Association in Contingency Tables.*—With qualitative data presented in the form of a contingency table in which association is known to exist, this association can be usefully interpreted as being due to the correlation between a pair of variates corresponding to the classes of the two classifications of the table. In the analysis of such data, two related approaches have been made, both of which have the distinct advantages of making tests of association more sensitive than the usual χ^2 test, and of providing numerical values for characterizing the classes of each classification.

A new technique for the analysis of data of this nature has now been devised. This analytical technique is formally related to the analysis for the interpretation of interactions (*see* Annual Report for 1950-51). It has been established that significance tests developed for discriminant analysis and for the interpretation of interactions, exact when the variates involved are normally distributed, may be applied as tests, asymptotically exact, to contingency tables.

(*b*) *A Mathematical Model for Stress-strain Relationships.*—One of the problems associated with the testing of materials under load, and one to which a great deal of attention has been directed, is the mathematical representation of the load-deformation curve. This has recently been re-examined, and a mathematical model devised to study the effects of an axial force on a fibre bundle for which the maximum load and the relation between load and deformation are determined. It has been shown that the model yields load-deformation curves closely similar in general appearance to those obtained in practice with a variety of materials, and the effect of rate of straining indicated by the model is qualitatively similar to that observed with wood under test.

(*c*) *The Mathematics of Counter-current Separation of Solutes.*—A theoretical investigation of the separation of pairs of solutes in a counter-current distribution train has been made. It has been shown that the numbers of tubes required to effect, to a predetermined degree of accuracy, the separation of two solutes with known partition coefficients can be derived from standard statistical tables. The results have been empirically verified in the prediction of the number of transfers necessary for the separation of aromatic aldehydes from the oxidative decomposition of lignins.

(d) *Applications of Component Analysis to the udy of Properties of Timber.*—This investigation of nponent analysis was made to show how the varia- n that occurs between different trees can be separated om that occuring within the tree, and the variation tween species can be separated from that occurring ween different trees of the same species. This type analysis is required in the derivation of valid stan- rd deviations for the average values of various pro- erties, and in making tests of significance. Component alysis is important also as a guide to sampling, and ethods of improving the efficiency of sampling by its e have been developed. The results of the investiga- on can be applied just as effectively with other types quantitative experimental data.

(e) *Interpolation in a Series of Correlated Observa- ons.*—The need to interpolate in a series of correlated bservations arises in many practical situations. For xample, the values of certain mechanical properties f timber are given only by a destructive test. It may e required to know the value of such a property for specimen before it is subjected to some other type f test. Some indirect method of determination of the roperty must then be used. If a number of specimens an be taken in series through the material, an estimate f the value of the property for the specimen considered may be derived from the values for those adjacent to it.

This problem has been investigated, and least squares ormulae have been obtained for estimating the values of unmeasured individuals of a series in which only alternate members are measured. The series is assumed to be, apart from a possible linear trend, a realization of a discrete stationary random process with a known correlation function.

The formulae are applicable to all sets of data which fulfil the required conditions.

3. COMPUTING INSTRUMENTS.

(a) *Analogue Instruments.*—The work on analogue instruments has been devoted mainly to operational use of the C.S.I.R.O. differential analyser. A considerable variety of problems has now been solved by the instrument for both research institutions and industrial organizations. As a result of operational experience, a number of modifications and extensions have been made to the differential analyser. These include the development of an integrand setting mechanism for the integrators and the incorporation of extra adding units, ratio units and plotting tables. In addition, thought is being given to the problem of developing an M-type transmission system giving a continuous motion instead of the step-by-step operation at present employed.

(b) *Digital Machines.*—Work on electronic devices for use with digital machines has been concentrated mainly on the development of beam-deflection type high-vacuum tubes for carrying out logical binary functions such as digit representation, addition and gating. An experimental model of a binary gating tube has been tested and has been found to work up to about 50 kc/s. In addition, construction of an electrostatic memory system has been continued.

(c) *Mark I. Electronic High-speed Computer.*—The Mark I. automatic computer was demonstrated during a conference on scientific computation held in Sydney in August, 1951. Since October the computer has been in regular use.

During the first few months many basic routines were developed and standardized for use as a library to aid in the later construction of programmes for full-scale computations. These included routines for performing operations such as reading decimal numbers and converting them into the binary scale for use by the computer, conversion of results to the decimal scale and page printing, division, square rooting, the evaluation of simple transcendental functions, and so on.

Recent work in the development of standard routines has included those for step-by-step integration of ordinary differential equations, basic functions for high-accuracy computations (twelve decimal digits, &c.) and the basic functions in floating form, both binary and decimal.

Computations performed following the initial development period have included: (i) time-series analyses of up to 1,000 entries; (ii) Fourier syntheses in three dimensions with 250 harmonic coefficients (for chemical structure analysis); (iii) data reduction (from radar tracking results); (iv) tabulation of integrals with singular integrands (for radio propagation theory); and (v) development of methods for the automatic solution of partial differential equations of various types.

In progress at present are computations which include: (i) computation of products of matrices; (ii) evaluation of determinants; and (iii) solution of sets of linear equations. All these involve the development of routines for matrix operations in floating form.

The machine is now operating for four to six hours each day at an efficiency of about 75 per cent., the main obstacle to greater use being lack of man-power on the programming staff, since programmers have to act also as machine operators.

Improvements are steadily being made to the machine. These finally will include the provision of adequate and convenient monitoring equipment, the construction of a control desk, the extension of the stores, and the provision of high-speed paper tape readers and tape puncher to replace the card reader and punch previously in use. Automatic editing equipment is also being provided in order to eliminate the effort and errors inherent in the process of coding by hand-punching.

(d) *Punched Card System.*—The punched card machines have been engaged largely on the computation of tables of functions for various users, and also on the computation of patterns of flow around spheres at Reynolds numbers between 1 and 10. Computations are made on the basis of Oseen's equations of viscous flow.

The punched card system has now been handed over to the Section of Mathematical Statistics.

(e) *Electronic Decade Counter Tube.*—Improvements have been made to the counter tube reported previously. The counter is a vacuum tube that counts in the decimal system and displays the number of the count. The incoming electrical signals are counted by triggering a single electron beam through a sequence of ten pairs of stable states. These stable states result from potential patterns created on a group of deflecting electrodes by distributions of the beam current. At each count a part of the beam current projects the corresponding figure, 0–9, on a fluorescent screen at the end of the bulb. When the beam traverses the count position " 0 " an output signal is passed to the following counter tube. The maximum rate of counting is between 70 and 180 kc/s. depending upon circuit conditions.

The development of the electronic counter tube has been taken to the stage at which it could be produced by a commercial manufacturer. The tube has a diameter of $1^3/_{16}$ inches and an over-all length of $4\frac{3}{8}$ inches. It requires an anode potential of 750 V. and a current of about 1 mA.

In designing the electron beam system for the counter tube, methods of calculating the defocusing of the electron beam due to space charges were investigated. As a result, a simple expression has been derived for relating the size of the beam spot with the length of the beam, the beam current, and the potential in any electron beam system.

XXXI. PUBLICATIONS AND INFORMATION.

1. General.

The Organization's research results are made available for application through various channels.

Formal publication is supplemented in several ways: by the preparation of films (Section 4 of this Chapter) which may, for example, give a farmer or extension officer more help in diagnosis of animal diseases than would a list of clinical data; by the continuous and close contact with industry of officers of the Divisions and Sections, through whom much information—derived from the literature, accumulated knowledge and experience, and current research—is disseminated; by the provision of facilities for guest workers in the laboratories; by the publication of trade circulars, newsletters, and articles for trade journals; by press releases; by lectures and short courses of specialized training: and by the organization of specialist conferences.

The application of research in the primary industries is being assisted by the work of the Agricultural Research Liaison Section established in 1951 (Section 3).

Other sections of this chapter describe the work of the Organization's Libraries (Section 5); the Translation Section (Section 6); the Information and Documentation Section (Section 7); and the Overseas Liaison Offices (Section 8).

2. Publications.

In collaboration with the Australian National Research Council the Organization publishes the *Australian Journal of Scientific Research* (Series A, dealing with the physical sciences, and Series B, dealing with the biological sciences) and, in collaboration with the Australian Institute of Agricultural Science and the Australian Veterinary Association, the *Australian Journal of Agricultural Research*. It also publishes the *Australian Journal of Applied Science*, the *Australian Journal of Marine and Freshwater Research*, and a series of Bulletins.

The Organization's research results are published in the above-mentioned journals, as Bulletins, and in papers contributed to specialized scientific journals both in Australia and overseas. The Organization's journals are also open to outside workers for the publication of papers of substantial merit.

A complete list of scientific papers by officers of the Organization, published during the year, will be found in Chapter XXXIV.

Rural Research in C.S.I.R.O. is a new periodical describing research of interest to the primary industries, designed mainly for extension workers. Closely associated with it is a new series of publications describing in non-technical language the results of sheep and wool research (*see* Section 3).

During the year three other important publications have been issued by the Organization—

(i) A new edition of the *Union Catalogue of Scientific and Technical Periodicals in Australian Libraries* (*see* Section 5).

(ii) A publication entitled *A Geneticist Talks with Australian Animal Breeders*, by Dr. A. L. Hagedoorn, a Dutch geneticist of world renown. The publication contains extracts from his addresses delivered throughout Australia and his answers to questions, which formed an important part of all the meetings addressed by him. Dr. Hagedoorn's approach is thoroughly practical, his exposition is lucid and simple, and his advice, which sometimes conflicts with widely held beliefs, is always supported by descriptions of his own experiments and observations.

(iii) Volume 1 of a monograph on *The Formicidae of Australia*, by John Clark. This volume deals with the subfamily Myrmeciinae; other volumes will follow. Mr. Clark has long been the outstanding authority on Australian ants, to the study of which he has devoted a large part of his life. On his retirement from the National Museum, Melbourne, the Organization provided the necessary finance to enable him to prepare and publish this monograph. Australian ants are of exceptional interest, for we have in this country the most primitive ants in the world. Because of their ubiquity and their incessant and varied activity, they occupy a conspicuous and often a dominating place in the ecology of most habitats.

3. Liaison between Agricultural Research and Extension Work.

The Agricultural Research Liaison Section was established in 1951 to ensure that important C.S.I.R.O. research results are made available speedily to State Departments of Agriculture for use in their extension work with farmers. These results are being marshalled and presented mainly through publications, conferences, and schools.

In assembling material for extension use, research work published over the last five years or so has been arranged in some order of importance as regards its value for extension purposes. Specialist conferences are an important source of this material, and during the year representatives of the Section attended those dealing with cereal genetics (Wagga), agrostology (Canberra), and salinity (Melbourne).

The Section is assisting in the preparation of the series of publications describing research financed from wool funds. The third in the series, entitled *Infertility Disease in Sheep Grazing Subterranean Clover*, was published, and three more are nearing completion.

The first number of a liaison periodical, *Rural Research in C.S.I.R.O.*, has appeared. This aims to describe results of important research by the Organization of interest to extension workers, administrators, and others. It is not intended for direct distribution to farmers, but extension authorities are encouraged to use this and similar material prepared by the Section as a basis for extension work with necessary alterations in matter and style to suit local conditions.

Conferences between research and extension officers are held to deal with more recent research results requiring detailed explanation and discussion. A school for sheep and wool extension officers from various States, organized in co-operation with the Queensland Department of Agriculture and Stock, was held in Brisbane in September, 1951. It dealt with recent research on statistics, reproduction, nutrition, and selection. A handbook of background information was prepared for the School and a summary of the more important " facts and pointers " concerning these subjects is being prepared for wider publication. The Section also helped in the organization and recording of the Canning Pea Conference (Melbourne, June, 1952), which dealt particularly with an important new technique for predicting the optimum harvest date for canning peas.

Discussions with some State Departments were held to consider the extension application of material presented at specialist conferences on irrigation (Griffith, 1950) and agrostology (Canberra, 1951). The New South Wales Department of Agriculture is organizing a two weeks' irrigation course for extension officers at Yanco Experiment Farm, and has appointed an organizing committee comprising representatives from the Department, the New South Wales Water Conservation and Irrigation Commission, and this Section.

The New South Wales Department of Agriculture is also taking the initiative in organizing a "conference tour" of research and extension officers to inspect field and laboratory work on pastures in the New South Wales Southern Tablelands, where recent research has shown that spectacular increases in carrying capacity are possible on several million acres. It is the policy of the Section to encourage State Departments of Agriculture, in co-operation with the Organization, to take the initiative in considering the application of recent research findings to specific regions.

The Section co-operated with the Film Unit and the New South Wales Department of Agriculture in the production of three irrigation films: "Salting and Soil Reclamation", "Better Ditches and Grades", and "Irrigation Farm Design". It also assisted with diagrams and other art work in a film entitled "Soils and Foundations". A large display illustrating wool research was prepared for the 1952 Sydney Sheep Show in co-operation with the Division of Animal Health and Production.

In general, the Section's policy is to direct its work to strictly liaison activities, working with research officers on the suitable presentation of their results and with extension authorities in considering the implications of those results in the extension field. The response to this policy has already shown that there is an important place for the Section, provided its function is kept clearly in view and overlapping of activities avoided.

4. FILM UNIT.

During the year the Film Unit has released the following 16-mm. films: "Chronic Phalaris Staggers in Sheep" (black and white, sound, 11 min.) is a record film showing the outward manifestations of the chronic stage of phalaris staggers, as shown by eight survivors from a flock of sheep, late in October, 1951—a similar record of the acute stage of the disease is in hand; "Egg White Substitute from Skim Milk" (black and white, silent, 6 min.) is also purely a record-type film of the industrial development of the process, which is based on laboratory work of the Dairy Research Section.

Owing to their highly specialized nature, both of these films have been released for limited distribution only.

A film entitled "Soils and Foundations" (colour, sound, 21 min.) has been completed. It deals with problems arising from the building of brick and masonry houses on certain troublesome types of clay soil.

A film, formerly entitled "The Origin and Control of Salting" which was listed as under production in the previous Report, has since been widened in scope and will soon be released as a 16-mm., colour, sound film, "Salting and Soil Reclamation".

Films on the following subjects are under production: "The Mutton Birds of Bass Strait", "Design for Irrigation", and "Supply and Drainage Ditches".

Films produced by the Unit have been widely screened in both the United Kingdom and the United States of America. The film "Division of Radiophysics 1949" was shown twice daily at the Festival of Britain, 1951, and also drew favorable comment at the International Scientific Film Congress held in Florence in October, 1950.

During the year copies of "Science and Wood" and "Purse Seining—a New Australian Fishery" have been obtained by the Food and Agriculture Organization of the United Nations for use in south-east Asia.

Films held in the central film library have been used extensively by borrowers from both within and without the Organization.

5. LIBRARIES.

The new edition of the *Union Catalogue of Scientific and Technical Periodicals in Australian Libraries* has been published. This catalogue, which was edited by Mr. E. R. Pitt, lists the titles of 67,000 scientific and technical periodicals published throughout the world and indicates in which of 248 libraries throughout Australia these will be found. These libraries include public, departmental, institutional, and also private company libraries. The subjects covered in the catalogue are all branches of science and the applied arts.

The previous edition, which was published in 1930, included 35,000 titles and 133 libraries. The marked increase, both in the titles of journals and in the number of co-operating libraries, is indicative of the remarkable increase in publication throughout the world of this type of literature.

The appearance of this new edition does not end the work. A supplement comprising all journals which have commenced publication since 1946 is now in preparation and records are being kept of alterations occurring in the periodical holdings of the co-operating libraries.

A bibliography on library literature and special library tools available in Head Office library was compiled and distributed to the more important special libraries throughout the Commonwealth.

Under the Commonwealth technical co-operation scheme, the Department of External Affairs arranged for librarians from India and the Philippines to visit Australia for a Library Seminar. Among the visitors were several in charge of scientific libraries in their home countries. They spent much of their time in the Head Office and Divisional libraries and mutually useful discussion of library problems resulted.

6. TRANSLATION SECTION.

The Section has carried out translation, written and oral, for the Organization's Divisions and Sections. Some use has been made of outside translators to relieve pressure of work.

The Section has collaborated in the production of the Translated Contents Lists of Russian Periodicals issued by the Department of Scientific and Industrial Research of Great Britain; has supplied the British Commonwealth Scientific Office with details of completed translations for inclusion in their index of translations; and has incorporated in its own card index cards received from the B.C.S.O. Lists of translations completed by the Section have been distributed to Divisions and Sections and to certain outside departments.

The languages handled by the Translation Section are German, Dutch, Swedish, Norwegian, Danish, Icelandic, Latin, French, Italian, Spanish, Portuguese, Hebrew, Russian, Polish, Ukrainian, Lettish and Hungarian. For other languages, use is made of a panel of outside translators.

7. Information and Documentation Section.

(*a*) *Information Service.*—In accordance with the policy outlined in the previous Report, the central Information Service has passed on a large proportion of inquiries received to C.S.I.R.O. laboratories and other specialist bodies. It has itself dealt only with inquiries not covered in this way. These have been relatively few and it has been possible for the Section to devote rather more time than formerly to the preparation of summarized information on specified subjects for the Executive. Five bibliographies were prepared in dealing with inquiries and a summary of information on jute and jute substitutes in Australia was prepared and issued in the T series of reports.

The distribution of unpublished reports received through the overseas Liaison Offices has continued but the volume of such material is now relatively small and, since most of it is for limited circulation, little distribution to industry has been possible. Reports in the PB series of the Office of Technical Services, United States of America, have been obtained in response to requests, and a steady demand for these has been maintained.

(*b*) *Documentation Section.*—The Section has continued to act as the local office for *Chemical Abstracts*, to provide secretarial services for the A.N.R.C. Committee on Scientific Information, and to collate data for the Phytochemical Register of Australian Flora.

During the year the Index to C.S.I.R.O. Publications was extended to include Divisional and Sectional reports. All material held has been author-indexed, and subject-indexing is proceeding.

A directory of Australian scientific societies was published and a directory of Australian scientific research centres was prepared for the British Commonwealth Scientific Conference held in Australia in February, 1952.

8. Overseas Liaison Offices.

The Organization maintains Scientific Liaison Offices in London and Washington as constituent units of the British Commonwealth Scientific Office (London) and the British Commonwealth Scientific Office (North America).

The work of the Liaison Offices is concerned with the exchange of scientific information, the location and collection of unpublished reports, and the procurement of specialized equipment. They also act as bases for visiting officers of the Organization and as points of contact with research students.

XXXII. PERSONNEL OF COUNCIL AND COMMITTEES.

1. Executive.

I. Clunies Ross, D.V.Sc. (*Chairman*).
F. W. G. White, M.Sc., Ph.D. (*Chief Executive Officer*).
S. H. Bastow, D.S.O., B.Sc., Ph.D.
H. J. Goodes, B. A.
A. B. Ritchie, M. A.

2. Advisory Council.

Chairman.

I. Clunies Ross, D.V.Sc.

Executive.

(*See* above.)

Chairmen of State Committees.

New South Wales—Professor J. P. Baxter, O.B.E., B.Sc., Ph.D.
Victoria—R. S. Andrews, D.Sc.
Queensland—A. F. Bell, M.Sc., D.I.C.
South Australia—Sir Kerr Grant, M.Sc.
Western Australia—Professor E. J. Underwood, B.Sc. (Agric.), Ph.D.
Tasmania—S. L. Kessell, M.B.E., M.Sc.

Co-opted Members.

D. T. Boyd, C.M.G.
Sir Harry Brown, C.M.G., M.B.E.
Sir Macfarlane Burnet, M.D., Ph.D., F.R.S.
Honorable O. McL. Falkiner, M.L.C.
W. A. Gunn.
W. S. Kelly, O.B.E.
E. H. B. Lefroy.
Sir John Madsen, B.E., D.Sc.
Professor D. M. Myers, D.Sc.
G. B. O'Malley, B.Met.E.
Sir David Rivett, K.C.M.G., M.A., D.Sc., F.R.S.
Professor S. M. Wadham, M.A.
Professor J. G. Wood, Ph.D., D.Sc.

3. State Committees.

New South Wales.

Professor J. P. Baxter, O.B.E., B.Sc., Ph.D. (*Chairman*).
C. J. Mulholland, B.Sc.
R. J. Noble, B.Sc.Agr., M.Sc., Ph.D.
A. R. Penfold.
Professor W. L. Waterhouse, M.C., B.Sc.Agr.
Professor J. D. Stewart, B.V.Sc.
Sir Frederick McMaster.
R. P. Okeden.
The Honorable Sir Norman Kater, M.L.C., M.B., Ch.M.
Emeritus Professor R. D. Watt, M.A., B.Sc.
J. Merrett.
W. R. Hebblewhite, B.E.
C. M. Williams.
J. G. Peake.
Professor Sir Henry Barraclough, K.B.E., V.D., B.E., M.M.E.
O. McL. Falkiner, M.L.C.
J. N. Briton, B.Sc., B.E.
E. L. S. Hudson.
J. P. Tivey, B.A., B.Sc., B.E.
Sir Harry Brown, C.M.G., M.B.E.
Sir John Madsen, B.E., D.Sc.
Professor D. M. Myers, D.Sc.
J. Vernon, B.Sc., Ph.D.
Associate Professor P. R. McMahon, M.Agr.Sc., Ph.D.
Professor J. R. A. McMillan, D.Sc.Agr., M.S.
F. S. Bradhurst.
V. J. F. Brain, B.E.
T. C. Roughley, B.Sc.
S. F. Cochran.
Professor H. R. Carne, D.V.Sc.
L.A. Pockley, B.V.Sc.

Victoria.

R. S. Andrews, D.Sc. (*Chairman*).
H. A. Mullett, B.Agr.Sc.
W. Baragwanath.
G. G. Jobbins.
Professor J. S. Turner, M.A,. Ph.D., M.Sc.
Professor P. MacCallum, M.C., M.A., M.Sc., M.B., Ch.B.
Professor J. N. Greenwood, D.Sc., M.Met.E.
W. E. Wainwright.
L. J. Weatherly, M.A.
H. Herman, D.Sc., M.M.E., B.C.E.
Sir Herbert Gepp.
Sir Dalziel Kelly, LL.B.
Sir Russell Grimwade, B.Sc.
Professor E. S. Hills, D.Sc., Ph.D., D.I.C.
Emeritus Professor H. A. Woodruff, B.Sc.
J. R. S. Cochrane, B.Sc.

ofessor E. J. Hartung, D.Sc.
. K. S. Brodribb, C.B.E.
r Macfarlane Burnet, M.D., Ph.D., F.R.S.
ofessor S. M. Wadham, M.A.
r David Rivett, K.C.M.G., M.A., D.Sc., F.R.S.
. T. Boyd, C.M.G.
. B. O'Malley, B.Met. E.
M. McLennan, B.E.E.
ssociate Professor G. W. Leeper, M.Sc.
. A. Hunt, D.S.O., B.C.E.

Queensland.

. F. Bell, M.Sc., D.I.C. (*Chairman*).
V. M. McLean, M.C.
. Veitch, B.Sc.Agr., B.Sc.For.
rofessor T. G. H. Jones, D.Sc., Ph.D.
rofessor D. A. Herbert, D.Sc.
. F. Meynink.
. McCann.
M. C. Urquhart, M.Sc.
. G. Grenning.
A. McCulloch, M.E.
. Michelmore.
Professor L. J. H. Teakle, M.S., B.Sc.(Agric.), Ph.D.
R. J. S. Muir.
R. J. Donaldson, D.S.O., B.C.E.
C. E. Young, D.S.O.
A. W. Campbell.
J. R. Duggan.
Professor T. K. Ewer, D.V.Sc.
B. Flewell-Smith, M.M.
R. L. Harrison.
C. H. Jamieson.
W. I. McLean.
Professor W. V. Macfarlane, M.A., M.D.
T. C. Marshall.
Professor M. Shaw, M.Eng., M.Mech.E.
Professor W. Stephenson, B.Sc., Ph.D.
S. A. Trout, M.Sc., Ph.D.
Professor H. C. Webster, D.Sc., Ph.D.
W. Webster, B.V.Sc.
Professor F. T. M. White, B.Met.E., B.E.
Associate Professor F. W. Whitehouse, Ph.D., D.Sc.
W. A. T. Summerville, D.Sc.
W. Young.
W. A. Gunn.
I. W. Morley, B.M.E., B.Met.E.

South Australia.

Sir Kerr Grant, M.Sc. (*Chairman*).
W. J. Spafford.
S. B. Dickinson, M.Sc.
S. B. Shiels.
Professor J. A. Prescott, C.B.E., D.Sc., F.R.S.
Professor M. L. Mitchell, M.Sc.
F. T. Perry, M.B.E.
A. J. Allen.
L. K. Ward, B.A., B.E., D.Sc.
Sir Douglas Mawson, O.B.E., D.Sc., B.E., F.R.S.
A. R. Callaghan, C.M.G., B.Sc., B.Sc.Agr., D.Phil.
H. R. Marston, F.R.S.
C. Haselgrove.
F. W. Moorhouse, M.Sc.
W. S. Kelly, O.B.E.
Professor J. G. Wood, Ph.D., D.Sc.

Western Australia.

Professor E. J. Underwood, B.Sc.(Agric.), Ph.D. (*Chairman*).
H. P. Rowledge.
A. L. McKenzie Clark, L.V.Sc.
T. N. Stoate, M.Sc.
Professor A. D. Ross, M.A., D.Sc.
B. Meecham.
Sir Langlois Lefroy.
F. G. Brinsden.
Professor N. S. Bayliss, B.A., B.Sc., Ph.D.
W. G. Burges.
Professor G. A. Currie, D.Sc., B.Agr.Sc.
G. L. Sutton, C.M.G., D.Sc.Agr.
Professor H. Waring, D.Sc.
H. Bowley.
G. K. Baron-Hay, M.C., B.Sc.(Agric.).
P. H. Harper, B.A.
E. H. B. Lefroy.
W. J. Russell.
C. R. Bunning.
D. W. Brisbane.
B. J. Grieve, M.Sc., Ph.D.
Professor R. T. Prider, B.Sc., Ph.D.
N. Temperley.
R. J. Dumas, C.M.G., M.E.
A. J. Fraser.
D. O. Temby, B.E.

Tasmania.

S. L. Kessell, M.B.E., M.Sc. (*Chairman*).
A. H. Crane.
A. W. Knight, B.Sc., M.E., B.Com.
F. W. Hicks.
J. Pearson, D.Sc.
Professor Alan Burn, M.Sc., B.E.
D. O. Meredith.
F. H. Peacock.
H. B. Somerset, M.Sc.
Sir Rupert Shoobridge, M.L.C.
L. R. Benjamin.
F. H. Foster, B.C.E.
Keith Brodribb.
T. A. Frankcomb.
N. F. Kirby, B.E.
Professor N. H. Barber, M.A., Ph.D.

4. COMMITTEE OF REVIEW—AGRICULTURAL AND PASTORAL PROBLEMS.

I. Clunies Ross, D.V.Sc., C.S.I.R.O. (*Chairman*).
L. B. Bull, C.B.E., D.V.Sc., Division of Animal Health and Production, C.S.I.R.O.
O. H. Frankel, D.Sc., D.Agr., Division of Plant Industry, C.S.I.R.O.
H. R. Marston, F.R.S., Division of Biochemistry and General Nutrition, C.S.I.R.O.
J. K. Taylor, B.A., M.Sc., B.Sc.Agr., Division of Soils, C.S.I.R.O.
A. J. Nicholson, D.Sc., Division of Entomology, C.S.I.R.O.
F. N. Ratcliffe, B.A., Wildlife Survey Section, C.S.I.R.O.
C. S. Christian, B.Sc.Agr., M.S., Land Research and Regional Survey Section, C.S.I.R.O.
H. C. Forster, M.Agr.Sc., Ph.D., C.S.I.R.O.
W. Ives, M.Ec., C.S.I.R.O. (*Secretary*).

5. COMMONWEALTH RESEARCH STATION, MERBEIN—TECHNICAL COMMITTEE.

Professor J. A. Prescott, C.B.E., D.Sc., F.R.S., Waite Agricultural Research Institute, University of Adelaide (*Chairman*).
J. K. Taylor, B.A., M.Sc., B.Sc.Agr., Division of Soils, C.S.I.R.O.
L. A. T. Ballard, Ph.D., M.Agr.Sc., Division of Plant Industry, C.S.I.R.O.
C. Barnard, D.Sc., Division of Plant Industry, C.S.I.R.O.
P. Malloch, Commonwealth Dried Fruits Control Board.
E. J. Casey, Commonwealth Dried Fruits Control Board.
J. R. Gordon, representing Consultative Committee.
F. Penman, M.Sc., Commonwealth Research Station, C.S.I.R.O., Merbein (*Secretary*).

6. Commonwealth Research Station, Merbein—Consultative Committee.

W. B. Hawson, First Mildura Irrigation Trust (*Chairman*).
L. W. Andrews, Waikerie, S.A.
N. Balcombe, Robinvale.
H. Broadfoot, Department of Agriculture, New South Wales.
A. E. Cameron, Red Cliffs Settlement.
E. J. Casey, representing Technical Committee.
D. W. Cockcroft, Nyah-Woorinen Enquiry Committee.
C. E. Cole, B.Agr.Sc., Department of Agriculture, Victoria.
W. V. Ford, Mildura Packers' Association.
J. R. Gordon, Citrus Growers' Association, Merbein.
A. E. Hazel, Dried Fruits Association, Red Cliffs.
S. Heaysman, Coomealla, New South Wales.
W. Heaysman, Cardross Progress Association.
H. Jackson, Wakool Land-use Committee.
J. A. Lochhead, Mildura Shire Council.
A. R. McDougall, Merbein.
P. Malloch, representing Technical Committee.
C. Mott, Dried Fruits Association, Woorinen.
C. T. Polkinghorne, Loxton North.
R. C. Polkinghorne, Nyah-Woorinen Enquiry Committee.
F. Richardson, Nyah-Woorinen Enquiry Committee.
J. L. Showell, Renmark Irrigation Trust.
A. G. Strickland, C.B.E., M.Agr.Sc., Department of Agriculture, South Australia.
A. L. Tisdall, M.Agr.Sc., State Rivers and Water Supply Commission, Victoria.
O. Weste, Renmark, South Australia.
F. Penman, M.Sc., Commonwealth Research Station, C.S.I.R.O., Merbein (*Secretary*).

7. Wakool Land-use Committee.

A. Varcoe-Cocks, Wakool Shire Council (*Chairman*).
F. Penman, M.Sc., Commonwealth Research Station, C.S.I.R.O., Merbein.
F. I. Bolton, Water Conservation and Irrigation Commission, New South Wales.
E. J. Williams, Rural Bank of New South Wales, Deniliquin.
K. Howe, Rural Bank of New South Wales, Deniliquin.
G. A. Crawford, Department of Agriculture, New South Wales.
K. Wood, Wakool District Landholders' Association.
D. Thomas, Wakool District Landholders' Association.
W. R. A. Smith, Wakool District Landholders' Association.
F. J. Hollins, Wakool District Landholders' Association.
L. A. Jeffers, Wakool District Landholders' Association.
F. Bock, Tullakool.
R. W. Prunster, B.Sc.(Agric.), Regional Pastoral Laboratory, C.S.I.R.O., Deniliquin.
H. Jackson, Wakool District Landholders' Association (*Secretary*).

8. Irrigation Research Station, Griffith—Technical Committee.

Professor J. A. Prescott, C.B.E., D.Sc., F.R.S., Waite Agricultural Research Institute, University of Adelaide.
H. N. England, B.Sc., Water Conservation and Irrigation Commission, New South Wales.
O. H. Frankel, D.Sc., D.Agr., Division of Plant Industry, C.S.I.R.O.
J. K. Taylor, B.A., M.Sc., B.Sc.Agr., Division of Soils, C.S.I.R.O
V. C. Williams, representing Irrigation Research and Extension Committee.
E. S. West, B.Sc., M.S., Irrigation Research Station, Griffith (*Secretary*).

9. Irrigation Research and Extension Committee (Murrumbidgee Irrigation Areas).

V. C. Williams, Griffith Producers' Co-op. Co. Ltd. (*Chairman*).
D. V. Walters, M.Agr.Sc., Department of Agriculture, New South Wales.
H. J. Hynes, D.Sc.Agr., M.S., Department of Agriculture, New South Wales.
P. F. Stanton, H.D.A., Organizer, M.I.A. Agricultural Service.
B. O. French, Yanco Experimental Farm.
W. R. Watkins, Department of Agriculture, New South Wales.
E. S. West, B.Sc., M.S., Irrigation Research Station, C.S.I.R.O., Griffith.
F. Penman, M.Sc., Commonwealth Research Station, C.S.I.R.O., Merbein.
R. W. Prunster, B.Sc.Agr., Regional Pastoral Laboratory, C.S.I.R.O., Deniliquin.
H. N. England, B.Sc., Water Conservation and Irrigation Commission, New South Wales.
H. Mallaby, H.D.A., Water Conservation and Irrigation Commission, New South Wales.
K. Woodyer, Water Conservation and Irrigation Commission, New South Wales.
S. Bowyer, Rural Bank of New South Wales.
G. E. B. Good, Rural Bank of New South Wales.
Professor J. R. A. McMillan, D.Sc.Agr., M.S., University of Sydney.
T. O'Rourke, Soil Conservation Service, New South Wales.
J. C. Byrne, Leeton Co-op. Cannery Ltd.
J. Ellis, M.I.A. Vegetable Growers' Association.
W. N. Hogan, M.I.A. District Council Extension Group.
P. Crook, M.I.A. District Council Extension Group.
G. S Denne, M.I.A. District Council Extension Group.
C. E. Sharman, Rice Growers' Association, Griffith.
C. Bowditch, Rice Growers' Association, Hanwood.

10. Regional Pastoral Centre, Deniliquin—Technical Committee.

O. H. Frankel, D.Sc., D.Agr., Division of Plant Industry, C.S.I.R.O.
L. B. Bull, C.B.E., D.V.Sc., Division of Animal Health and Production, C.S.I.R.O.
J. K. Taylor, B.A., M.Sc., B.Sc.Agr., Division of Soils, C.S.I.R.O.
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A. Morgan, B.Agr.Sc., Department of Agriculture, Victoria.
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F. Penman, M.Sc., Commonwealth Research Station, C.S.I.R.O., Merbein.
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. T. Boyd, C.M.G., Woorooma East, Moulamein, New South Wales.

. McL. Falkiner, M.L.C., Boonoke Station, Conargo, New South Wales.

. C. Burston, "Yallambee", Mulwala, New South Wales.

. Woodside, Boree Plains, Benerembah Irrigation District, Griffith, New South Wales.

. W. Crosbie, Belvedere Park, Berriquin Irrigation District, Finley, New South Wales.

. R. Ennals, Cobram Irrigation District, Cobram, Victoria.

. R. Varco-Cocks, "Nullabooma", Wakool Irrigation District, Wakool.

. I. Bolton, Water Conservation and Irrigation Commission, New South Wales.

. L. Tisdall, M.Agr.Sc., State Rivers and Water Supply Commission, Victoria.

. K. Vears, B.Sc.Agr., Department of Agriculture, New South Wales.

A. Morgan, B.Agr.Sc., Department of Agriculture, Victoria.

R. W. Prunster, B.Sc. (Agric.), Regional Pastoral Laboratory, C.S.I.R.O., Deniliquin (*Secretary*).

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J. G. Davies, B.Sc., Ph.D., Division of Plant Industry, C.S.I.R.O.

D. A. Gill, M.R.C.V.S., D.V.S.M., Division of Animal Health and Production, C.S.I.R.O.

G. Edgar, B.V.Sc., Department of Agriculture, New South Wales.

J. N. Whittet, H.D.A., Department of Agriculture, New South Wales.

I. L. Johnstone, B.V.Sc., Division of Animal Health and Production, C.S.I.R.O. (seconded to A.S.L.O., London).

R. Roe, B.Sc.(Agric.), Division of Animal Health and Production, C.S.I.R.O. (*Acting Secretary*).

13. REGIONAL PASTORAL CENTRE, ARMIDALE—CONSULTATIVE COMMITTEE.

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A. H. Voisey, D.Sc., New England University College.

A. G. Brett, Graziers' Association of New South Wales.

G. E. Forster, Graziers' Association of New South Wales.

H. F. White, Graziers' Association of New South Wales.

A. W. Weller, Northern New South Wales Farmers' Union.

L. P. Dutton, Council of Advice to the Pasture Protection Board, New South Wales.

Sir Hugh Croft, co-opted member.

S. Payne, Council of Advice to the Pasture Protection Board, New South Wales.

G. Edgar, B.V.Sc., Department of Agriculture, New South Wales.

J. N. Whittet, H.D.A., Department of Agriculture, New South Wales.

E. C. Powell, New England Regional Development Committee.

J. G. Davies, B.Sc., Ph.D., Division of Plant Industry, C.S.I.R.O.

I. L. Johnstone, B.V.Sc., Division of Animal Health and Production, C.S.I.R.O. (seconded to A.S.L.O., London).

R. Roe, B.Sc.(Agric.), Division of Animal Health and Production, C.S.I.R.O. (*Acting Secretary*).

14. "GILRUTH PLAINS" TECHNICAL COMMITTEE.

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C. M. Donald, M.Ag.Sc., Division of Plant Industry, C.S.I.R.O.

R. B. Kelley, D.V.Sc., Division of Animal Health and Production, C.S.I.R.O.

W. A. T. Summerville, D.Sc., Queensland Department of Agriculture and Stock.

W. Webster, B.V.Sc., Queensland Department of Agriculture and Stock.

J. F. Kennedy, M.Agr.Sc., Division of Animal Health and Production C.S.I.R.O. (*Secretary*).

15. JOINT BLOWFLY CONTROL COMMITTEE.

(Appointed as a means of co-ordinating the activities of the New South Wales Department of Agriculture, the Queensland Department of Agriculture and Stock, and the Organization.)

L. B. Bull, C.B.E., D.V.Sc., Division of Animal Health and Production, C.S.I.R.O. (*Chairman*).

A. J. Nicholson, D.Sc., Division of Entomology, C.S.I.R.O.

G. Edgar, D.V.Sc., Glenfield Veterinary Research Station, Department of Agriculture, New South Wales.

H. G. Belschner, D.V.Sc., Department of Agriculture, New South Wales.

T. McCarthy, Department of Agriculture, New South Wales.

W. Webster, B.V.Sc., Department of Agriculture and Stock, Queensland.

F. H. S. Roberts, D.Sc., Division of Animal Health and Production, C.S.I.R.O.

D. A. Gill, M.R.C.V.S., D.V.S.M., Division of Animal Health and Production, C.S.I.R.O. (*Secretary*).

16. JOINT VETERINARY PARASITOLOGY COMMITTEE.

W. Webster, B.V.Sc., Department of Agriculture and Stock, Queensland (*Chairman*).

J. Legg, D.V.Sc., Department of Agriculture and Stock, Queensland.

F. H. S. Roberts, D.Sc., Division of Animal Health and Production, C.S.I.R.O.

L. F. Hitchcock, M.Sc., Division of Entomology, C.S.I.R.O.

Miss H. F. Todd, C.S.I.R.O. (*Secretary*).

17. ADVISORY COMMITTEE ON FRUIT COOL STORAGE INVESTIGATIONS IN NEW SOUTH WALES.

J. R. Vickery, M.Sc., Ph.D., Division of Food Preservation and Transport, C.S.I.R.O. (*Chairman*).

H. Broadfoot, Department of Agriculture, New South Wales.

Professor N. A. Burges, M.Sc., Ph.D., Department of Botany, University of Sydney.

R. N. Robertson, B.Sc., Ph.D., Division of Food Preservation and Transport, C.S.I.R.O.

F. T. Bowman, Ph.D., M.Sc., B.Sc.Agr., Department of Agriculture, New South Wales.

R. B. Withers, M.Sc., Dip.Ed., Division of Food Preservation and Transport, C.S.I.R.O. (*Secretary*).

18. Committee for Co-ordination of Fruit and Vegetable Storage Research.

A. G. Strickland, C.B.E., M.Agr.Sc., Department of Agriculture, South Australia (*Chairman*).
W. J. Bettenay, B.Sc.(Agric.), Department of Commerce and Agriculture, Melbourne.
S. M. Sykes, B.Sc.Agr., Department of Agriculture, New South Wales.
C. E. Cole, B.Agr.Sc., Department of Agriculture, Victoria.
T. D. Raphael, M. A., Dip. Hort. (Cambridge), Department of Agriculture, Tasmania.
R. N. Robertson, B.Sc., Ph.D., Division of Food Preservation and Transport, C.S.I.R.O.
D. Martin, B.Sc., Division of Plant Industry, C.S.I.R.O.
S. A. Trout, M.Sc., Ph.D., Department of Agriculture and Stock, Queensland.
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19. Consultative Committee on Food Investigations and Standards.

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R. F. Turnbull, B.E., Division of Forest Products, C.S.I.R.O.
G. Loftus Hills, B.Agr.Sc., Dairy Research Section, C.S.I.R.O.
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W. J. Wiley, D.Sc., Department of Commerce and Agriculture, Melbourne.
H. R. Tinney, B.V.Sc., Department of Commerce and Agriculture, Melbourne.
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20. Committee for Co-ordination of Research on Fruit and Vegetable Processing.

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S. M. Sykes, B.Sc.Agr., Department of Agriculture, New South Wales.
E. G. Hallsworth, B.Sc., Ph.D., School of Agriculture, University of Sydney.
R. B. Withers, M.Sc., Dip.Ed., Division of Food Preservation and Transport, C.S.I.R.O. (*Secretary*).

21. Dried Fruits Processing Committee.

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F. H. Colbey, Department of Commerce and Agriculture, Adelaide.
F. Penman, M.Sc., Commonwealth Research Station, C.S.I.R.O., Merbein.
E. C. Orton, B.Sc., Commonwealth Research Station, C.S.I.R.O., Merbein.
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J. D. Bryden, H.D.A., Department of Agriculture, New South Wales.
D. G. Quinn, R.D.A., Department of Agriculture, Victoria.
B. G. Coombe, B.Agr.Sc., Department of Agriculture, South Australia (*Secretary*).

22. Advisory Committee on Fruit Storage—Investigations in Victoria.

C. E. Cole, B.Agr.Sc., Department of Agriculture, Victoria (*Convenor and Secretary*).
S. Fish, M.Agr.Sc., Department of Agriculture, Victoria.
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23. Mildura District Dried Vine Fruits Processing Committee.

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A. E. Hazel, Dried Fruits Association, Red Cliffs.
W. Heaysman, representing Merbein Advisory Committee.
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N. A. Johnson, Irymple, Victoria.
F. Penman, M.Sc., Commonwealth Research Station, C.S.I.R.O., Merbein.
K. H. C. McCallum, Red Cliffs, Victoria.
A. R. McDougall, Merbein, Victoria.
S. R. Mansell, Mildura, Victoria.
B. Bromley, Red Cliffs, Victoria.
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I. Thomas, Department of Agriculture, Western Australia.
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M. M. H. Wallace, B.Sc., Division of Entomology, C.S.I.R.O.
R. P. Roberts, M.Sc.(Agric.) (*Secretary*).

25. Kimberley Research Station Supervisory Committee.

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C. M. Dimond, Public Works Department, Western Australia.
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W. M. Nunn, Department of Agriculture, Western Australia (*Executive Officer*).

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Professor J. B. Cleland, M.D., Ch.M., representing the University of Adelaide.
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R. P. Donnelly, Government Chemical Laboratory, Western Australia.
J. R. Duggan, B.Sc., B.E., Colonial Gas Association, Queensland.
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W. Baragwanath, Melbourne.
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29. Kalgoorlie Ore-dressing Sub-committee.

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C. S. Wiggins, Department of Civil Aviation.
Wing-Commander J. W. Reddrop, Director of Telecommunications and Radar, R.A.A.F.
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D. Stewart, B.E., Australian National Airways Ltd.
F. E. Coate, Australian National Airlines Commission.
E. P. Wright, B.Sc., Postmaster-General's Department.
Captain N. K. J. Felstead, Australian Air Pilots' Association.
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F. G. Nicholls, M.Sc., C.S.I.R.O. (*Secretary*).

35. Building Research Committee.

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J. W. Drysdale, Department of Works.
R. E. Banks, B.Sc.(Eng.), Department of Works.
A. L. Brentwood, B.C.E., B.E.E., Department of Labour and National Service.
S. A. Clarke, B.E., Division of Forest Products, C.S.I.R.O.
W. F. Evans, B.Sc., Division of Building Research, C.S.I.R.O. (*Secretary*).

36. Catalogue of Scientific and Technical Periodicals—Editorial Committee.

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C. A. McCallum, B.A., Chief Librarian, Public Library of Victoria.
Ellinor Archer, M.Sc., Chief Librarian, C.S.I.R.O.

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Professor J. C. Jaeger, D.Sc., M.A., Australian National University.
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E. G. Bowen, O.B.E., M.Sc., Ph.D., Division of Radiophysics, C.S.I.R.O.
R. W. Boswell, M.Sc., Long Range Weapons Establishment, Department of Supply.
H. A. Wills, B.E., Department of Supply.
T. Pearcey, B.Sc., Division of Radiophysics, C.S.I.R.O.
W. R. Blunden, B.Sc., B.E., Section of Mathematical Instruments, C.S.I.R.O. (*Secretary*).

XXXIII. STAFF.

The following is a list of the staff of the Organization as at June 30, 1952. The list does not include clerical staff, typists, laboratory assistants, and miscellaneous workers.

1. Head Office.

(Head-quarters: 314 Albert-street, East Melbourne.)
Chairman—I. Clunies Ross, D.V.Sc.
Chief Executive Officer—F. W. G. White, M.Sc., Ph.D.
Executive Officer—S. H. Bastow, D.S.O., B.Sc., Ph.D.
Secretary—G. A. Cook, M.C., M.Sc., B.M.E.
Assistant Executive Officer—H. C. Forster, M.Agr.Sc., Ph.D.
Assistant Secretary—F. G. Nicholls, M.Sc.
Assistant Secretary—G. B. Gresford, B.Sc.
Assistant Secretary—W. Ives, M.Ec.
Assistant Secretary (Finance and Supplies)—M. G. Grace, A.I.C.A.
Assistant Secretary—D. T. C. Gillespie, M.Sc.
Senior Research Officer—J. F. H. Wright, B.Sc.
Senior Research Officer—A. B. Cashmore, M.Sc.
Research Officer—P. F. Butler, M.Sc.Agr.
Research Officer—Miss J. Dunstone, B.Sc., Dip.Ed.
Research Officer—G. J. Wylie, B.A., B.Sc.
Research Officer—Miss J. McL. Baldwin, B.Sc., Dip.Ed.
Research Officer—G. J. Walker, M.Sc.
Technical Officer—Miss G. M. Lesslie, B. Sc.
Architect—W. R. Ferguson, B.E.
Assistant to Architect—N. Schmidt.
Draughtsman, Grade II.—W. J. Widdowson.
Electrical and Mechanical Engineer—R. N. Morse, B.Sc., B.E.

Editorial—
Editor—N. S. Noble, D.Sc.Agr., M.S., D.I.C.
Senior Research Officer—R. W. Bond, B.Sc.
Research Officer—R. W. Crabtree, B.Sc.
Research Officer—Miss L. F. Plunkett, B.Sc.
Research Officer—Miss M. Walkom, B.A.

Library—
Chief Librarian—Miss E. Archer, M.Sc.
Librarian—Miss A. L. Kent.
Librarian—Miss F. V. Murray, M.Sc.
Librarian—Miss J. Conochie, B.Sc.
Librarian—Miss B. C. L. Doubleday, M.A.
Librarian—Miss I. J. McPhail, B.Sc. (at Brisbane).
Senior Assistant Librarian—Miss T. Koetsier, B.A.

Accounts, Finance, Stores—
Accountant—D. J. Bryant, A.F.I.A.
Finance Officer—R. W. Viney, A.I.C.A., A.C.I.S.
M. A. Elliott.

Orders and Transport—
J. M. Derum.

Staff—
Staff and Industrial Officer—H. E. Waterman, A.F.I.A.
R. D. Elder.

Records—
P. Knuckey.

Publications—
Senior Technical Officer—T. R. Hunter.

Central Experimental Workshops—
Engineer-in-charge—F. G. Hogg, B.E.
Plant Engineer—K. A. Robeson, B.Mech.E.
Assistant Engineer—J. Kowalczewski, Dipl. Ing.
Assistant Engineer—R. Medding, B.E.E.
Chief Draughtsman—G. T. Stephens, Dip. Mech. Eng., Dip. Elec. Eng.
Draughtsman, Grade II.—F. Wickham, Dip. Mech. Eng.
Draughtsman, Grade II.—J. R. Mitchell, Dip. Mech. Eng., Dip Elec. Eng.
Draughtsman, Grade II.—W. J. Fatchen, Dip. Mech. Eng., Dip. Elec. Eng.

Liaison Overseas—
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Chief Scientific Liaison Officer—J. E. Cummins, B.Sc., M.S.
Principal Research Officer—I. L. Johnstone,
Senior Research Officer—A. B. Hackwell, B.Agr.Sc.
Washington—
Scientific Liaison Officer—A. J. Higgs, B.Sc.

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Senior Translator—A. L. Gunn.
Translator—E. Feigl, Ph.D.
Translator—Mrs M. Slade.
Translator—Miss P. A. Gibson, B.A.
Translator—H. E. Kylstra, B.A.
In Sydney—
Translator—C. Wouters, D. ès L.

Film Unit—
Research Officer—S. T. Evans, B.Sc.

Agricultural Research Liaison Section—
Officer-in-charge—R. R. Pennefather, B.Agr.Sc.
Research Officer—A. F. Gurnett-Smith, B.Agr.Sc., Q.D.D.
Technical Officer—L. H. Kelly.
Technical Officer—B. W. Muirden.

2. Secretaries of State Committees.

New South Wales—
A. M. Andrews, B.Sc., Wall House, 18 Loftus-street, Sydney.

Victoria—
F. G. Nicholls, M.Sc., 314 Albert-street, East Melbourne.

Queensland—
Miss H. F. Todd, 113 Eagle-street, Brisbane.

South Australia—
(Vacant.)

Western Australia—
R. P. Roberts, M.Sc.(Agric.), Department of Agriculture, Perth.

Tasmania—
D. Martin, B.Sc., "Stowell", Stowell-avenue, Hobart.

3. Animal Genetics.

At Sydney—
Senior Principal Research Officer—J. M. Rendel, B.Sc., Ph.D.
Research Officer—A. S. Fraser, M.Sc., Ph.D.

4. Division of Animal Health and Production.

(Head-quarters: Cr. Flemington-road and Park-street, Parkville, Melbourne.)

At Divisional Head-quarters, Melbourne—
Chief—L. B. Bull, C.B.E., D.V.Sc.
Divisional Secretary—A. J. Vasey, B.Agr.Sc.

Assistant Divisional Secretary—N. M. Tullah, M.Agr.Sc.

At Animal Health Research Laboratory, Melbourne—

Assistant Chief of Division and Officer-in-charge—A. W. Turner, O.B.E., D.Sc., D.V.Sc.

Principal Research Officer—T. S. Gregory, D.V.Sc. Dip.Bact.

Principal Research Officer—D. Murnane, D.V.Sc.

Principal Research Officer—R. H. Watson, D.Sc. Agr.

Principal Research Officer—A. T. Dick, M.Sc.

Senior Research Officer—A. D. Campbell, L.V.Sc.

Senior Research Officer—A. T. Dann, M.Sc.

Research Officer—A. W. Rodwell, M.Sc., Ph.D.

Research Officer—Mrs. E. S. Rodwell, M.A., Ph.D.

Research Officer—J. B. Bingley, D.A.C.

Research Officer—Miss C. E. Bales, B.Sc. (on leave).

Research Officer—Miss M. J. Monsborough, B.Sc.

Research Officer—H. G. Turner, B.Agr.Sc., M.A.

Research Officer—G. Alexander, B.Agr.Sc. (on study leave).

Research Officer—H. M. Radford, B.Sc.

Research Officer—Miss V. E. Hodgetts, B.Sc.

Research Officer—J. S. McKenzie, B.Sc.

Technical Officer—M. W. Mules.

Technical Officer—E. Wold.

Technical Officer—A. E. Wright.

Technical Officer—J. J. Spencer.

Technical Officer—R. A. Fookes.

Technical Officer—N. E. Southern.

Technical Officer—I. S. Goldman.

Technical Officer—F. Whitehead.

Technical Officer—J. R. Etheridge.

Librarian—Miss F. V. Murray, M.Sc. (part-time).

Senior Assistant Librarian—Mrs. Y. Sutherland.

Survey of Beef Cattle Production—

Senior Research Officer—W. A. Beattie, B.A., M.A., LL.B.

At Field Station, Werribee, Victoria—

Dairy Cattle Investigations—

Technical Officer—L. C. Gamble.

Poultry Breeding Investigations—

Senior Research Officer—F. Skaller, M.Agr.Sc., B.Com. (on leave).

Research Officer—J. A. Morris, B.Sc.Agr.

Research Officer—G. W. Grigg, M.Sc. (on study leave).

Technical Officer—T. E. Allen, B.Sc.

Technical Officer—W. J. Lloyd.

Technical Officer—Miss L. W. Böbr, M.Sc. (Agr.).

At McMaster Animal Health Laboratory, Sydney—

Assistant Chief of Division and Officer-in-charge (pathology)—D. A. Gill, M.R.C.V.S., D.V.S.M.

Principal Research Officer—H. McL. Gordon, B.V.Sc.

Principal Research Officer—M. C. Franklin, M.Sc., Ph.D. (abroad).

Principal Research Officer—D. F. Stewart, B.V.Sc., Dip.Bact.

Senior Research Officer—C. R. Austin, M.Sc., B.V.Sc.

Senior Research Officer—R. L. Reid, B.Sc.Agr., Ph.D.

Research Officer—M. D. Murray, B.V.Sc., M.R.C.V.S.

Research Officer—B. A. Forsyth, B.V.Sc.

Research Officer—W. K. Warburton, LL.B., B.Sc. (on study leave).

Research Officer—A. W. H. Braden, B.Sc.

Research Officer—V. Massey, B.Sc. (on study leave).

Research Officer—Miss M. T. Scott, B.Sc. (on leave).

Research Officer—R. I. Somerville, M.Sc.Agr.

Research Officer—Miss H. B. Esserman, B.Sc.

Research Officer—P. R. Whitfield, B.Sc.

Research Officer—C. H. Gallagher, B.V.Sc.

Research Officer—Miss J. H. Koch, M.D.

Ian McMaster Research Scholar—P. K. Briggs, B.Sc.Agr.

Technical Officer—H. A. Offord.

Technical Officer—F. J. Hamilton.

Technical Officer—H. V. Whitlock.

Technical Officer—G. C. Merritt.

Technical Officer—A. C. Juleff.

Technical Officer—B. L. Campbell.

Clerk—H. H. Wilson.

Librarian—Miss A. G. Culey, M.Sc. (on leave).

Senior Assistant Librarian—Mrs. B. Sommerville.

At Department of Veterinary Physiology, University of Sydney—

Officer-in-charge, Sheep Biology Laboratory—C. W. Emmens, D.Sc., Ph.D. (part-time).

At Wool Biology Laboratory, Sydney—

Officer-in-charge—H. B. Carter, B.V.Sc.

Senior Research Officer—Miss M. H. Hardy, M.Sc., Ph.D.

Research Officer—K. Ferguson, B.V.Sc.

Research Officer—B. F. Short, M.Sc.Agr.

Research Officer—J. H. Elliott, B.Sc.

Technical Officer—D. L. Hall.

Technical Officer—W. H. Clarke.

Sheep Breeding Investigations—

Research Officer—A. A. Dunlop, M.Agr.Sc., Ph.D.

At Fleece Analysis Laboratory, Villawood, New South Wales—

Officer-in-charge—N. F. Roberts, M.Sc.

Research Officer—L. T. Wilson, B.Sc.

Technical Officer—Miss L. Folley (on leave).

At Regional Pastoral Laboratory, Armidale, New South Wales—

Officer-in-charge—I. L. Johnstone, B.V.Sc., (on leave).

Acting Officer-in-charge—R. Roe, B.Sc.(Agric.)

Research Officer—J. F. Barrett, B.V.Sc.

Research Officer—W. H. Southcott, B.V.Sc.

Technical Officer—V. D. Prentice, O.B.E.

Technical Officer—P. B. Sutton.

Technical Officer—Miss L. C. Lawrence.

Technical Officer—R. J. Lewis.

Technical Officer—J. W. Carr.

Technical Officer—R. L. Rocks.

At F. D. McMaster Field Station, Badgery's Creek, New South Wales—

Assistant Chief of Division and Officer-in-charge—R. B. Kelley, D.V.Sc. (abroad).

Research Officer—R. H. Hayman, B.Agr.Sc.

At Animal Genetics Unit (at University of Sydney)—

Cattle Breeding Investigations—

Research Officer—D. F. Dowling, B.V.Sc., B.Sc., Ph.D.

At Regional Pastoral Laboratory, Deniliquin, New South Wales—

Sheep Breeding Investigations—

Technical Officer—F. S. Richardson, B.Agr.Sc.

At Veterinary Parasitology Laboratory, Yeerongpilly. Queensland—

Officer-in-charge—F. H. S. Roberts, D.Sc.

Research Officer—P. H. Durie, B.Sc.

Research Officer—R. S. Riek, B.V.Sc.

Technical Officer—R. K. Keith.

Survey of Fine Wool Production—

Senior Research Officer—J. H. Riches, B.Sc.Agr., Ph.D.

At Department of Physiology, University of Queensland, Brisbane—

Research Officer—N. M. T. Yeates, B.Sc.Agr., Ph.D.

At National Field Station, "Gilruth Plains", Cunnamulla, Queensland—
Officer-in-charge—J. F. Kennedy, M.Agr.Sc.
Research Officer—C. H. S. Dolling, B.Agr.Sc., R.D.A.
Technical Officer—P. H. G. Sheaffe.
Technical Officer—F. J. Willett.

At Western Australian Department of Agriculture, Animal Health and Nutrition Laboratory, Nedlands, Western Australia—
Senior Research Officer—A. B. Beck, M.Sc.

At Institute of Agriculture, University of Western Australia, Nedlands, Western Australia—
Senior Research Officer—E. Munch-Petersen, M.Sc., B.A., M.I.F.

5. Atomic Physics.

At Physics Department, University of Melbourne—
Research Officer—K. B. Mather, B.Sc.(Eng.), M.Sc.
Research Officer—J. R. Prescott, B.Sc., Ph.D.
Research Officer—J. H. Parry, M.Sc.
Research Officer—W. B. Lasich, M.Sc., Ph.D.
Technical Officer—D. R. Ellis.

Tracer Elements Section (at University of Melbourne)—
Principal Research Officer—T. H. Oddie, D.Sc.
Research Officer—A. M. Downs, M.Sc.
Research Officer—K. R. Lynn, B.Sc.

At Atomic Energy Research Establishment, Harwell, England—
Principal Research Officer—O. O. Pulley, B.Sc., B.E., Ph.D.
Principal Research Officer—C. D. Boadle, B.M.E.
Senior Research Officer—J. N. Gregory, M.Sc.
Senior Research Officer—N. A. Faull, B.Sc.
Senior Research Officer—G. L. Giles, B.A., M.Sc., Ph.D.
Research Officer—D. F. Sangster, B.Sc.

6. Division of Biochemistry and General Nutrition.

(Head-quarters: University of Adelaide.)

Chief—H. R. Marston, F.R.S.
Divisional Secretary—L. G. Peres, B.Ec. (acting).
Principal Research Officer—A. W. Peirce, D.Sc.
Principal Research Officer—D. S. Riceman, M.Sc., B.Agr.Sc.
Principal Research Officer—H. J. Lee, M.Sc.
Senior Research Officer—E. W. Lines, B.Sc.
Senior Research Officer—F. V. Gray, M.Sc.
Senior Research Officer—Miss M. C. Dawbarn, M.Sc. (part-time).
Senior Research Officer—I. G. Jarrett, M.Sc.
Senior Research Officer—G. B. Jones, M.Sc.
Senior Research Officer—T. A. Quinlan-Watson, M.Sc.
Research Officer—L. J. Frahn, Ph.D., M.Sc.
Research Officer—Miss S. H. Allen, B.Sc.
Research Officer—R. F. Passey, B.Sc.Agr.
Research Officer—A. F. Pilgrim, B.Sc.
Research Officer—B. J. Potter, M.Sc.
Research Officer—J. K. Powrie, M.Sc., B.Sc.(Agric.) (on leave).
Research Officer—R. M. Smith, B.Sc.
Research Officer—R. A. Weller, B.Sc.
Research Officer—R. E. Kuchel, B.Sc.
Research Officer—Miss D. Hine, M.Sc.
Senior Technical Officer—D. W. Dewey.
Senior Technical Officer—R. H. Jones, R. D. A.
Technical Officer — R. E. Underdown, B.Sc., A.S.A.S.M.
Technical Officer—R. M. Sangster, R.D.A.
Technical Officer—V. A. Stephen.
Technical Officer—J. O. Wilson (part-time).
Technical Officer—D. F. Graham.
Technical Officer—C. E. Sleigh.
Technical Officer—R. F. Trowbridge.
Technical Officer—E. Talbot-Smith.
Senior Assistant Librarian—Miss P. M. Smith.

7. Biophysical Research.

At University of Tasmania—
Research Officer—A. B. Hope, B.Sc.

8. Division of Building Research.

(Head-quarters: Graham-road, Highett, Victoria.)

Administration—
Chief—I. Langlands, M.Mech.E., B.E.E.
Technical Secretary—W. F. Evans, B.Sc.

Information and Library—
Senior Research Officer—J. R. Barned, B.Sc.
Research Officer—R. C. McTaggart, B.Sc.
Research Officer—Mrs. C. M. Petrie, M.A., Ph.D. (part-time).
Technical Officer—E. S. Smith.
Librarian—Mrs. S. A. Curwen.

Physical and Mechanical Testing Laboratory—
Research Officer—R. E. Lewis, B.Sc.
Technical Officer—F. D. Beresford, A.M.T.C.
Technical Officer—W. U. S. Falk, F.M.T.C.
Technical Officer—J. J. Russell.

Concrete Investigations—
Research Officer—F. A. Blakey, B.E., Ph.D.
Research Officer—W. H. Taylor, M.C.E.
Technical Officer—E. N. Mattison.

Masonry Investigations—
Principal Research Officer—J. S. Hosking, M.Sc., Ph.D.
Senior Research Officer—H. V. Hueber, Dr. Phil.
Senior Research Officer—W. F. Cole, M.Sc., Ph.D.
Research Officer—J. A. Ferguson, M.Sc., Ph.D.
Research Officer—R. D. Hill, B.Sc., B.Com.
Research Officer—Mrs. T. Demediuk, Dr.Phil.
Technical Officer—A. R. Carthew, B.Sc.
Technical Officer—Miss M. E. Neilson, B.Sc.
Technical Officer—A. E. Holland, A.M.T.C.
Technical Officer—Miss A. Feldman.

Surfacing Materials Investigations—
Senior Research Officer—E. H. Waters, M.Sc.
Research Officer—J. E. Bright, B.Sc.
Technical Officer—D. A. Powell, B.Sc.
Technical Officer—I. McLachlan.

Acoustics and Thermal Investigations—
Senior Research Officer—R. W. Muncey, M.E.E.
Research Officer—A. F. B. Nickson, M.Sc.
Research Officer—W. K. R. Lippert, Dr.Phil.
Research Officer—T. S. Holden, B.Sc.
Technical Officer—P. Dubout, B.Sc.
Technical Officer—Miss V. R. Goullet, B.Sc.
Technical Officer—A. W. Wilson.

Organic Materials Investigations—
Senior Research Officer—B. M. Holmes, M.Sc.
Research Officer—E. R. Ballantyne, B.Sc.
Technical Officer—N. G. Brown, A.M.T.C.
Technical Officer—J. W. Spencer, B.Sc.
Technical Officer—D. N. Crook, A.Sw.T.C.

9. Coal Research Section.

(Head-quarters: Delhi-road, North Ryde, New South Wales.)

Administration—
Officer-in-charge—H. R. Brown, B.Sc.(Eng.).
Technical Secretary—A. M. Andrews, B.Sc.
Librarian—Miss R. Southami, B.Sc.

emical Properties—

Principal Research Officer—H. Berry, M.Sc. (Tech.)
Research Officer—H. N. S. Schafer, B.Sc.
Senior Technical Officer—M. S. Burns.
Technical Officer—A. Wlasow, Dipl. Chem., Dipl. Ing.
Technical Officer—Mrs. B. J. Nivison-Smith, B.Sc.
Technical Officer—T. P. Maher, B.Sc.
Technical Officer—A. J. Ryan, B.Sc.

oal and Coal Tar Chemistry—

Principal Research Officer—G. E. Mapstone, M.Sc.
Technical Officer—J. W. Smith.
Technical Officer—B. Nartsissov, M.Chem.
Technical Officer—J. Szewczyk, M. Phys., Dipl. Ing.Chem.

hysical Chemistry—

Senior Research Officer—J. D. Brooks, B.Sc.
Research Officer—M. Kossenberg, Ph.D.
Technical Officer—Miss A. J. Dunbar, A.S.T.C.
Technical Officer—H. S. Hancock, B.Sc.

etrography—

Research Officer—B. E. Balme, B.Sc.
Technical Officer—J. P. F. Hennelly, B.Sc.

ombustion and Ignition—

Senior Research Officer—N. Y. Kirov, M.Sc.

arbonization—

Research Officer—R. H. Jones, B.Sc.
Technical Officer—J. T. Munday, B.E.(Chem.).

10. Commonwealth Research Station (Murray Irrigation Areas).

(Head-quarters: Merbein, Victoria.)

Officer-in-charge—F. Penman, M.Sc.
Principal Research Officer—E. C. Orton, B.Sc.
Senior Research Officer—J. G. Baldwin, B.Agr.Sc., B.Sc.
Research Officer—G. V. F. Clewett, B.E.
Research Officer—W. J. Webster, B.Sc.
Research Officer—A. J. Antcliff, B.Sc.
Research Officer—M. R. Sauer, B.Agr.Sc.
Research Officer—S. F. Bridley, B.Agr.Sc.
Research Officer—R. C. Woodham, B.Agr.Sc.
Research Officer—D. McE. Alexander, B.Sc.
Senior Technical Officer—J. E. Giles.
Technical Officer—G. L. Stott, A.S.T.C.
Senior Assistant Librarian—Miss J. M. Flenley.
District Officer (Nyah-Woorinen)—R. C. Polkinghorne (part-time).
District Officer (Wakool)—H. Jackson (part-time).
District Officer (Renmark)—J. V. Seekamp, B.Agr.Sc. (part-time).

11. Dairy Research Section.

(Head-quarters: Lorimer-street, Fishermen's Bend Victoria.)

Officer-in-charge—G. Loftus Hills, B.Agr.Sc.
Principal Research Officer—N. King, M.Sc.
Senior Research Officer—E. G. Pont, M.Sc.Agr.
Senior Research Officer—K. Kumetat, Ph.D.
Senior Research Officer—J. Conochie, B.Sc.(Agric.).
Research Officer—A. J. Lawrence, B.Sc.
Research Officer—D. A. Forss, M.Sc.
Research Officer—J. Czulak, B.Sc.(Agr.), Dip.Bact.
Research Officer—J. W. Lee, B.Sc.

12. Division of Electrotechnology.

(Head-quarters: National Standards Laboratory at University of Sydney.)

Chief—F. J. Lehany, M.Sc.
Technical Secretary—R. C. Richardson, B.E.
Principal Research Officer—W. K. Clothier, B.Sc., M.E.
Senior Research Officer—A. M. Thompson, B.Sc.
Senior Research Officer—L. G. Dobbie, M.E.
Senior Research Officer—R. J. Meakins, B.Sc., Ph.D., D.I.C.
Senior Research Officer—B. V. Hamon, B.Sc., B.E.
Senior Research Officer—D. L. Hollway, B.E.E., M.Eng.Sc. (abroad).
Research Officer—J. S. Dryden, M.Sc., Ph.D., D.I.C.
Research Officer—G. J. A. Cassidy, B.E.E.
Research Officer—T. M. Palmer, Dipl.F.H.
Research Officer—H. K. Welsh, M.Sc.
Research Officer—D. W. Posener, M.Sc. (abroad).
Research Officer—Miss J. W. Mulley, A.S.T.C.
Research Officer—D. G. Lampard, M.Sc.
Research Officer—J. J. O'Dwyer, B.Sc., B.E., Ph.D.
Research Officer—D. L. H. Gibbings, B.E., Ph.D.
Research Officer—G. J. Johnson, B.Sc.
Research Officer—W. E. Smith, B.Sc.
Principal Technical Officer—L. Medina, Dipl.Ing.
Senior Technical Officer—L. M. Mandl, Dipl.Ing., A.S.T.C.
Senior Technical Officer—F. C. Brown, A.S.T.C.
Technical Officer—R. W. Archer, A.S.T.C.
Technical Officer—H. A. Smith, A.S.T.C.
Technical Officer—R. V. Single.
Technical Officer—H. C. Collins, A.S.T.C.
Techanical Officer—J. M. Melano, A.S.T.C.
Technical Officer—Miss M. C. Clark, B.Sc., A.S.T.C.
Technical Officer—H. Bairnsfather.
Technical Officer—E. Cowcher, B.A., A.S.T.C.
Technical Officer—M. C. McGregor, A.S.T.C.
Technical Officer—F. C. Hawes, A.S.T.C.
Technical Officer—Miss P. M. G. Thompson, B.Sc.
Technical Officer—R. P. Hoffman.
Technical Officer—E. Robertson, A.S.T.C.
Technical Officer—R. E. Holmes, A.S.T.C.
Technical Officer—N. L. Brown, A.S.T.C.

13. Division of Entomology.

(Head-quarters: Canberra, Australian Capital Territory.)

At Canberra—

Administration—

Chief—A. J. Nicholson, D.Sc.
Technical Secretary—K. L. Taylor, B.Sc.Agr.
Librarian—Miss J. Humphreys, B.A., Dip.Ed. (half-time).
Librarian—Miss J Rosenberg, B.A. (half-time).
Chief Clerk—K. J. Prowse (half-time).
Deputy Chief Clerk—D. W. Banyard (half-time).
Technical Officer—L. A. Marshall.
Technical Officer—D. H. Wilson.
Technical Officer—W. J. Rafferty.

Biological Control—

Principal Research Officer—F. Wilson.
Research Officer—E. F. Riek, M.Sc.
Research Officer—G. J. Snowball, B.Sc. (on study leave).
Technical Officer—G. R. Wearne.
Technical Officer—J. Citowitsch, Dip.Biol.

Museum—

Research Officer—T. G. Campbell.

Taxonomy of Diptera—

Senior Research Officer—S. J. Paramonov, D.Sc.

Physiology and Toxicology—

Principal Research Officer—D. F. Waterhouse, D.Sc.
Senior Research Officer—D. Gilmour, M.Sc.
Research Officer—R. F. Powning, A.S.T.C.
Research Officer—R. H. Hackman, M.Sc., Ph.D.
Technical Officer—L. G. Webber, B.Sc.
Technical Officer—H. Irzykiewicz.
Technical Officer—Miss M. Lazarus, B.Sc.
Technical Officer—Mrs. M. M. Goldberg, B.Sc.

Insecticide Investigations—
Research Officer—R. W. Kerr, B.Sc.
Locust, Grasshopper, and Cockchafer Investigations—
Principal Research Officer—K. H. L. Key, D.Sc.
Research Officer—P. B. Carne, B.Agr.Sc. (on study leave).
Technical Officer—L. J. Chinnick, R.D.A.
Virus Vector Investigations—
Senior Research Officer—M. F. Day, B.Sc., Ph.D.
Research Officer—A. L. Dyce, B.Sc.Agr.
Technical Officer—N. E. Grylls, D.D.A.
Technical Officer—Mrs. M. J. Bennetts, B.Sc.
Termite Investigations—
Senior Research Officer—F. J. Gay, B.Sc., D.I.C.
Technical Officer—A. Wetherley.
Sheep Blowfly Investigations—
Senior Research Officer—K. R. Norris, M.Sc.
Technical Officer—K. Laucis.
Ant Investigation—
Research Officer—T. Greaves.
Population Dynamics—
Chief of Division—A. J. Nicholson, D.Sc.
Senior Technical Officer—A. T. Mills.
Technical Officer—S. Dee.
Pasture Caterpillar Investigations—
Research Officer I. F. B. Common, M.A., B.Agr.Sc.
Stored Products Pests Investigations—
Research Officer—S. W. Bailey, B.Sc., A.R.C.S.

At Yeerongpilly, Queensland—
Cattle Tick Investigations—
Senior Research Officer—L. F. Hitchcock, M.Sc.
Research Officer—W. J. Roulston, B.Sc.
Technical Officer—R. A. J. Meyers, Q.D.A.H., Q.D.D.

At Rockhampton, Queensland—
Cattle Tick Investigations—
Research Officer—P. R. Wilkinson, M.A.
Technical Officer—J. T. Wilson, Q.D.A.

In Western Australia—
Earth Mite and Lucerne Flea Investigations—
Research Officer—M. M. H. Wallace, B.Sc.
Technical Officer—J. A. Mahon, Dip.D.Sci.

At Bright, Victoria—
St. John's Wort Investigations—
Senior Research Officer—L. R. Clark, M.Sc. (abroad).

14. DIVISION OF FISHERIES.

(Head-quarters: Cronulla, New South Wales.)

At Cronulla—
Chief—H. Thompson, M.A., D.Sc.
Technical Secretary—Mrs. L. M. Willings, B.A.
Senior Principal Research Officer—G. W. Rayner, M.Sc.
Principal Research Officer—E. J. Ferguson Wood, B.A., M.Sc.
Senior Research Officer—M. Blackburn, D.Sc.
Senior Research Officer—D. J. Rochford, B.Sc.
Research Officer—I. S. R. Munro, M.Sc. (abroad).
Research Officer—A. M. Rapson, M.Sc.
Research Officer—R. S. Spencer, B.Sc.
Research Officer—G. S. Grace, B.Sc.
Research Officer—Miss P. Kott, M.Sc.
Research Officer—T. W. Houston, B.Sc.
Technical Officer—J. P. Robins, B.Sc.
Technical Officer—Miss B. B. Dew, B.A.
Technical Officer—F. E. Allen.
Marine Superintendent — Commander R. H. Thornton (abroad).
Senior Technical Officer—A. Proctor.
Technical Officer—G. A. Gordon.
Technical Officer—A. Temple.

At Melbourne—
Technical Officer—P. E. Gartner, B.Sc.
At Perth—
Research Officer (Officer-in-charge).—K. Sheard, M.Sc.
Research Officer—W. B. Malcolm, B.Sc.
Research Officer—R. G. Chittleborough, B.Sc.
Technical Officer—H. R. Jitts, B.Sc.
Technical Officer—A. Middleton.
At Hobart—
Senior Research Officer—A. G. Nicholls, B.Sc., Ph.D.
Research Officer—A. M. Olsen, M.Sc.
Research Officer—A. H. Weatherley, B.Sc.
Research Officer—T. R. Cowper, B.Sc.
At Dunwich, Queensland—
Research Officer—J. M. Thomson, M.Sc.
Technical Officer—D. J. Dunstan, B.Sc.
At Thursday Island, Queensland—
Research Officer—J. S. Hynd, B.Sc.
Research Officer—J. B. Sless, M.Sc.

15. DIVISION OF FOOD PRESERVATION AND TRANSPORT.

(Head-quarters: State Abattoir, Homebush Bay, New South Wales.)

At Homebush, New South Wales—
Administration and General—
Chief—J. R. Vickery, M.Sc., Ph.D.
Technical Secretary — R. B. Withers, M.Sc., Dip.Ed.
Librarian—Miss B. Johnston, B.Sc.
Senior Assistant Librarian—Miss J. Hicks.
Physics and Transport Section—
Principal Research Officer—E. W. Hicks, B.A., B.Sc.
Senior Research Officer—M. C. Taylor, M.Sc.
Research Officer—G. M. Rostos, Dipl.Ing.
Research Officer—H. L. Evans, M.Sc.
Technical Officer—M. B. Smith, A.S.A.S.M.
Technical Officer—J. D. Mellor.
Microbiology Section—
Principal Research Officer—W. J. Scott, B.Agr.Sc.
Research Officer—M. R. J. Salton, B.Sc.Agr. (abroad).
Research Officer—W. G. Murrell, B.Sc.Agr., D.Phil.
Research Officer—J. H. B. Christian, B.Sc.Agr.
Technical Officer—P. R. Maguire.
Technical Officer—D. F. Ohye, D. I. C.
Technical Officer—Miss B. J. Marshall, A.S.T.C.
Biochemistry—
Principal Research Officer—F. E. Huelin, B.Sc., Ph.D.
Research Officer—J. B. Davenport, M.Sc.
Organic Chemistry—
Senior Research Officer—Miss T. M. Reynolds, M.Sc., D.Phil.
Research Officer—A. S. F. Ash, B.Sc., Ph.D.
Fruit and Vegetable Storage Section—
Principal Research Officer—R. N. Robertson, B.Sc., Ph.D.
Research Officer—J. F. Turner, M.Sc. (abroad).
Research Officer—Miss J. M. Bain, M.Sc.
Technical Officer—T. J. Riley, H.D.A.
Canning and Fruit Products Section—
Principal Research Officer—L. J. Lynch, B.Agr.Sc.
Senior Research Officer—J. F. Kefford, M.Sc.
Senior Research Officer—R. S. Mitchell, M.Sc.Agr.
Research Officer—B. V. Chandler, B.Sc.
Research Officer—E. G. Davis, B.Sc.
Research Officer—P. W. Board, B.Sc.

Dried Foods Section—
Research Officer—D.McG. McBean, B.Sc.
Technical Officer—F. Fitzpatrick, A.S.T.C.
Fish Investigations—
Principal Research Officer—W. A. Empey, B.V.Sc.
Technical Officer—R. Allan.
Meat and Egg Investigations—
Chief—J. R. Vickery, M.Sc., Ph.D.
Senior Research Officer—A. R. Riddle, A.B., M.S.
Technical Officer—F. S. Shenstone, A.S.T.C.
Freezing of Fruit and Vegetables—
Research Officer—I. J. Tinsley, B.Sc.
At Auburn, New South Wales—
Meat Dehydration Investigations—
Research Officer—A. R. Prater, B.Sc.Agr.
At Botany School, University of Sydney—
Plant Cell Physiology Investigations—
Principal Research Officer—R. N. Robertson, B.Sc., Ph.D.
Senior Research Officer—H. S. McKee, B.A., D.Phil.
Research Officer—Miss M. Wilkins, M.Sc.
Research Officer—Mrs. J. Pearson, M.Sc.
Technical Officer—Mrs. G. Urbach, M.Sc.
Technical Officer—Mrs. L. Nesztel, B.Sc.
At Biochemistry School, University of Sydney—
Physical Chemistry Section—
Research Officer—H. A. McKenzie, M.Sc.
Fish Investigations—
Technical Officer—Mrs. H. S. Wallace, A.S.T.C.
At Tasmanian Regional Laboratory, Hobart—
Canning and Fruit Products—
Technical Officer—R. A. Gallop, A.S.T.C.
Fish Investigations—
Technical Officer—K. W. Anderson, A.M.T.C.
At Brisbane, Queensland—
Meat Investigations—
Officer-in-charge—A. Howard, M.Sc.
Senior Research Officer—G. Kaess, Dr.Ing.
Research Officer—A. D. Brown, M.Sc.
Technical Officer—N. T. Russell, D.I.C.
Technical Officer—P. E. Bouton, B.Sc.
With United Kingdom Ministry of Food—
Senior Research Officer—N. E. Holmes, B.E.E., M.Mech.E. (seconded).
With Commonwealth Department of Commerce and Agriculture, London—
Senior Research Officer—E. G. Hall, B.Sc.Agr. (seconded).
With Commonwealth Department of Commerce and Agriculture, Melbourne—
Research Officer—J. Shipton, B.Sc.Agr. (seconded).

16. Division of Forest Products.

(Head-quarters: 69 Yarra Bank-road, South Melbourne, Victoria.)

Administration—
Chief—S. A. Clarke, B.E.
Assistant to Chief—C. S. Elliot, B.Sc.
Assistant to Chief—H. E. Dadswell, D.Sc.
Technical Secretary—F. A. Priest, A.S.A.S.M.
Information Officer—A. P. Wymond, M.Sc.
Librarian—Miss M. I. Hulme.
Senior Assistant Librarian—Miss A. Forbes.
Senior Technical Officer—L. Santer, Dip.Eng.
Wood Structure Section—
Senior Principal Research Officer-in-charge—H. E. Dadswell, D.Sc.
Senior Research Officer—G. L. Amos, M.Sc.
Senior Research Officer—Miss M. M. Chattaway, M.A., B.Sc., D.Phil.
Senior Research Officer—H. D. Ingle, B.For.Sc.
Senior Research Officer—A. B. Wardrop, M.Sc., Ph.D.
Research Officer—P. R. Wilkinson, B.Sc.
Technical Officer—Miss M. F. Day, B.Sc.
Technical Officer—C. F. James, B.Sc.
Photography—
Technical Officer—W. G. Hastie.
Technical Officer—Miss Audrey Lightfoot.
Wood Chemistry Section—
Senior Principal Research Officer-in-charge—W. E. Cohen, D.Sc.
Senior Research Officer—D. E. Bland, M.sc.
Senior Research Officer—H. G. Higgins, B.Sc. (part-time).
Research Officer—D. H. Foster, M.Sc.
Research Officer—W. E. Hillis, M.Sc., A.G.Inst. Tech.
Research Officer—A. von Koeppen, Dr.Ing.
Research Officer—R. C. McK. Stewart, B.Sc.
Research Officer—A. J. Watson, A.M.T.C.
Technical Officer—A. G. Charles.
Technical Officer—Miss M. F. Gatley, B.Sc.
Technical Officer—J. A. McPherson, B.Sc.
Technical Officer—Miss G. Schwerin, B.Sc.
Timber Physics Section—
Principal Research Officer-in-charge—R. S. T. Kingston, B.Sc., B.E.
Research Officer—L. N. Clarke, B.Eng.Sc.
Research Officer—Miss K. E. Kelsey, B.Sc.
Technical Officer—L. D. Armstrong.
Technical Officer—N. C. Edwards, A.S.M.B.
Technical Officer—P. U. A. Grossman, Ph.A.Mr.
Technical Officer—J. W. P. Nicholls, B.Sc.
Timber Mechanics Section—
Principal Research Officer-in-charge—K. L. Cooper, M.A., B.Sc.
Senior Research Officer—J. D. Boyd, M.C.E.
Research Officer—N. H. Kloot, M.Sc.
Research Officer—R. G. Pearson, B.A., B.C.E.
Technical Officer—Miss E. A. Blair, B.Sc.
Technical Officer—J. J. Mack.
Technical Officer—K. Schuster, A.M.T.C.
Timber Seasoning Section—
Principal Research Officer-in-charge—G. W. Wright, M.E.
Senior Research Officer—J. W. Gottstein, B.Sc.
Research Officer—E. L. Ellwood, M.Sc. (For.) (abroad).
Technical Officer—L. J. Brennan.
Technical Officer—G. S. Campbell.
Technical Officer—F. J. Christensen.
Technical Officer—H. D. Roberts.
Timber Preservation Section—
Principal Research Officer-in-charge—N. Tamblyn, M.Sc. (Agric.).
Research Officer—G. N. Christensen, M.Sc. (abroad).
Research Officer—E. W. B. da Costa, M.Agr.Sc.
Research Officer—G. W. Tack, B.Agr.Sc.
Research Officer—Miss S. J. Wilson, M.Sc.
Senior Technical Officer—F. A. Dale, F.M.T.C.
Technical Officer—T. E. Aplin, B.Sc.
Technical Officer—J. Beesley, B.Sc.(For.), Dip.For.
Technical Officer—D. F. McCarthy, A.M.T.C.
Technical Officer—Miss N. Robinson.
Technical Officer—A. Rosel.
Veneer and Gluing Section—
Senior Research Officer-in-charge—A. Gordon, B.Sc.
Senior Research Officer—H. G. Higgins, B.Sc. (part-time).
Research Officer—K. F. Plomley, B.Sc.(Agr.).
Technical Officer—Miss D. R. Fraser, B.Sc.
Technical Officer—K. Hirst.

Utilization Section—

Principal Research Officer-in-charge — R. F. Turnbull, B.E.
Research Officer—W. M. McKenzie, B.Sc.(For.).
Technical Officer—S. J. Colwell, A.M.T.C.
Technical Officer—R. L. Cowling, Dip.Mech.Eng., Dip.E.E.

Maintenance Section—

Senior Technical Officer—S. G. McNeil.

17. Division of Industrial Chemistry.

(Head-quarters: Lorimer-street, Fisherman's Bend, Victoria.)

Administration—

Chief—I. W. Wark, D.Sc., Ph.D.
Divisional Secretary—L. Lewis, B.Met.E.
Assistant Secretary—A. E. Scott, M.Sc.

Minerals Utilization Section—

Senior Principal Research Officer—R. G. Thomas, B.Sc.
Principal Research Officer—A. Walkley, B.A., D.Sc., Ph.D. (abroad).
Senior Research Officer—T. R. Scott, D.Sc., B.Ed.
Senior Research Officer—A. W. Wylie, M.Sc., Ph.D.
Research Officer—R. C. Croft, M.Sc.
Research Officer—P. Dixon, M.Sc.
Research Officer—P. M. J. Gray, B.Sc., A.R.S.M.
Research Officer—J. H. Green, M.Sc., Ph.D.
Research Officer—F. R. Hartley, M.Sc.
Research Officer—J. D. Hayton, B.Sc. (at S.A. School of Mines, Adelaide).
Research Officer—I. E. Newnham, M.Sc.
Research Officer—E. S. Pilkington, A.S.T.C.
Research Officer—R. C. Vickery, D.Sc., Ph.D.
Research Officer—A. D. Wadsley, M.Sc.
Senior Technical Officer—H. R. Skewes, A.A.C.I.

Cement and Ceramics Section—

Senior Principal Research Officer—A. R. Alderman, D.Sc., Ph.D.
Principal Research Officer—W. O. Williamson, B.Sc., Ph.D.
Principal Research Officer—G. F. Walker, B.Sc., Ph.D.
Senior Research Officer—H. E. Vivian, B.Sc.Agr.
Part-time Officer—A. J. Gaskin, M.Sc.
Research Officer—K. M. Alexander, M.Sc., Ph.D.
Research Officer—S. M. Brisbane, B.A., A.M.T.C.
Research Officer—G. M. Bruere, M.Sc.
Research Officer—C. E. S. Davis, B.Sc.
Research Officer—H. Ellerton (at Bonython Research Laboratory, S.A. School of Mines, Adelaide).
Research Officer—H. R. Samson, M.Sc. (on study leave).
Research Officer—E. R. Segnit, M.Sc., Ph.D.
Research Officer—L. S. Williams, D.Phil., B.E.
Senior Technical Officer—J. D. Wolfe.
Technical Officer—Miss M. Ball, B.Sc.
Technical Officer—R. W. Cox, F.M.T.C.
Technical Officer—A. C. Frostick.
Technical Officer—R. R. Hughan.
Technical Officer—Miss B. C. Terrell, B.Sc.
Technical Officer—J. Wardlaw, B.Sc.
Technical Officer—J. H. Weymouth, B.Sc.

Foundry Sands Section—

Senior Research Officer—H. A. Stephens, B.Sc.
Technical Officer—P. W. Goad, A.M.T.C.
Technical Officer—A. N. Waterworth, A.H.T.C.

Chemical Physics Section—

Senior Principal Research Officer—A. L. G. Rees, D.Sc., Ph.D.
Senior Research Officer—A. Walsh, M.Sc.Tech.
Senior Research Officer—E. H. Mercer, B.Sc., Ph.D. (abroad).
Senior Research Officer—J. L. Farrant, M.Sc.
Senior Research Officer—A. McL. Mathieson, B.Sc., Ph.D.
Senior Research Officer—D. A. Davies, B.Sc.
Research Officer—J. M. Cowley, M.Sc., Ph.D.
Research Officer—J. D. Morrison, B.Sc., Ph.D.
Research Officer—J. B. Willis, M.Sc., Ph.D.
Research Officer—A. F. Moodie, B.Sc. (abroad).
Research Officer—C. Billington, B.A.
Research Officer—B. Dawson, M.Sc., Ph.D.
Research Officer—J. P. Shelton, M.Sc., A.B.S.M.
Research Officer—A. J. Hodge, B.Sc., Ph.D. (on study leave).
Research Officer—J. V. Sullivan, M.Sc. (at University of Western Australia, Perth).
Research Officer—N. S. Ham, M.Sc.
Research Officer—P. Goodman, M.Sc.
Research Officer—J. Fridrichsons, M.Sc.
Research Officer—A. F. Beecham, B.Sc.
Research Officer—J. C. Riviere, M.Sc. (on study leave).
Research Officer—A. J. C. Nicholson, M.Sc., Ph.D.
Research Officer—C. K. Coogan, M.Sc., Ph.D.
Research Officer—J. O. Cope, M.Sc., Ph.D.
Research Officer—W. C. T. Dowell, M.Sc.
Research Officer—Miss L. Hulme, B.Sc.
Senior Technical Officer—W. G. Jones.
Senior Technical Officer—S. E. Powell.
Senior Technical Officer—G. F. H. Box.
Technical Officer—E. Cakanovskis, Dipl.Ing.
Technical Officer—F. B. Williams.

Physical Chemistry Section—

Principal Research Officer—K. L. Sutherland, D.Sc., Ph.D.
Senior Research Officer—V. Garten, D.Sc.
Senior Research Officer—M. E. Winfield, M.Sc., Ph.D.
Research Officer—J. Bowler Reed, B.Sc., Ph.D.
Research Officer—W. E. Ewers, M.Sc.
Research Officer—J. A. Barker, B.A., B.Sc.
Research Officer—I. Brown, B.Sc.
Research Officer—H. G. David, B.Sc. at Department of Chemical Engineering, University of Sydney).
Research Officer—A. Ewald, B.Sc. (on leave).
Research Officer—S. D. Hamann, M.Sc., Ph.D. (at Department of Chemical Engineering, University of Sydney).
Research Officer—B. W. Wilson, M.Sc.
Research Officer—D. E. Weiss, B.Sc.
Research Officer—E. A. Swinton, B.Sc.
Research Officer—W. W. Mansfield, B.Sc. (at N.S.W. University of Technology).
Senior Technical Officer—L. F. Evans, D.S.M.B.
Technical Officer—W. Fock, B.Sc.
Technical Officer—R. McNeil, A.S.T.C.
Technical Officer—M. Linton, B.Sc.
Technical Officer—M. Ross, Ing.

Organic Chemistry Section—

Senior Principal Research Officer—H. H. Hatt, D.Sc., Ph.D.
Principal Research Officer—J. R. Price, M.Sc., D.Phil.
Principal Research Officer—W. Zimmermann, D.Ing.
Senior Research Officer—J. S. Fitzgerald, M.Sc., Ph.D.
Senior Research Officer—R. G. Curtis, M.Sc., D.I.C.
Senior Research Officer—K. E. Murray, B.Sc. (abroad).
Research Officer—C. S. Barnes, M.Sc. (on study leave).

Research Officer—R. B. Bradbury, B.Sc.Agr., D.B.S.M. (at University of Western Australia, Perth).
Research Officer—W. D. Crow, M.Sc. (on study leave).
Research Officer—C. C. J. Culvenor, Ph.D., D.Phil.
Research Officer—L. K. Dalton, A.S.T.C.
Research Officer—H. Duewell, B.Sc., Ph.D.
Research Officer—N. C. Hancox, M.Sc.
Research Officer—R. J. L. Martin, M.Sc., Ph.D.
Research Officer—H. Silberman, Ph.D.
Research Officer—J. A. Lamberton, B.Sc., Ph.D.
Technical Officer—E. Gellert, Ph.D.
Technical Officer—A. W. McKenzie, A.M.T.C.
Technical Officer—A. H. Redcliffe, Dip.Anal. Chem.M.U.
Technical Officer—Miss E. E. Rutherford, B.Sc.
Technical Officer—R. Schoenfeld, B.Sc.

Chemical Engineering Section—
Senior Research Officer—R. W. Urie, B.Sc., S.M.
Research Officer—D. Barrett, M.Sc.
Research Officer—T. J. Birch, B.Sc.
Research Officer—K. E. Calderbank, M.Sc.
Research Officer—K. R. Hall, B.Sc.
Research Officer—O. G. Ingles, M.Sc.
Research Officer—A. G. Parts, M.Sc., Ph.D.
Research Officer—E. M. Rossiter, B.Sc.
Research Officer—P. Terry, B.Sc.
Research Officer—A. B. Whitehead.
Research Officer—Miss E. M. W. Leake, B.Sc.
Senior Technical Officer—J. B. Ross, B.Sc., A.M.T.C.
Technical Officer—J. L. Clay, A.M.T.C.
Technical Officer—K. W. Foley, B.Sc.
Technical Officer—K. F. Drinan, B.Sc.
Technical Officer—E. F. Symons, A.M.T.C.
Technical Officer—D. H. Trethewey, A.M.T.C.
Sectional Draughtsman—C. Simpson.

At University of Western Australia—Alunite Investigations—
Research Officer—D. F. A. Koch, B.Sc.

At Division of Plant Industry, Canberra—
Research Officer—W. Bottomley, M.Sc. (seconded).

At Division of Electrotechnology, Sydney—
Senior Research Officer—R. J. Meakins, B.Sc., Ph.D. (seconded).
Research Officer—Miss J. W. Mulley, A.S.T.C. (seconded).
Research Officer—H. K. Welsh, B.Sc. (seconded).

Photography—
Technical Officer—F. D. Lugton.

Library—
Librarian—Miss B. M. Brown, B.Sc.
Senior Assistant Librarian—Miss S. M. Wheeler.

18. Irrigation Research Station (Murrumbidgee Irrigation Areas).

(Head-quarters: Griffith, New South Wales.)

Officer-in-charge—E. S. West, B.Sc., M.S.
Senior Research Officer—R. F. Williams, M.Sc.
Senior Research Officer—L. A. Whelan, M.Sc., Ph.D.
Research Officer—O. Perkman, B.Sc.Agr.
Research Officer—V. J. Wagner, B.Sc.Agr.
Research Officer—E. L. Greacen, B.Sc.Agr., Ph.D.
Research Officer—H. J. Frith, B.Sc.Agr.
Research Officer—C. T. Gates, B.Sc.Agr.
Senior Technical Officer—B. H. Martin, H.D.A.
Technical Officer—A. N. Huon.
Technical Officer—Miss J. Connor, B.Sc.
Senior Assistant Librarian—Miss M. Russell.

Seconded to New South Wales Department of Agriculture—
Senior Research Officer—D. V. Walters, M.Agr.Sc.
Research Officer—Mrs. J. Tully, B.Sc., Ph.D.

19. Land Research and Regional Survey Section.

(Head-quarters: Canberra, Australian Capital Territory.)

At Head-quarters, Canberra—
Officer-in-charge—C. S. Christian, B.Sc.Agr., M.S.
Technical Secretary—Miss M. Mills, B.Sc.
Principal Research Officer—E. Phillis, Ph.D., D.Sc.
Research Officer—R. O. Slatyer, B.Sc.(Agric.).

At Ayr, Queensland—
Research Officer—F. H. Kleinschmidt, B.Sc.(Agr.)
Technical Officer—P. R. Farrell, Q.D.A.

At Kimberley Research Station, Western Australia—
Research Officer—L. C. Lee, B.Agr.Sc.
Technical Officer—E. C. B. Langfield.
Technical Officer—P. J. Cheetham, Q.D.H.

At Katherine Research Station, Northern Territory—
Research Officer—W. Arndt, B.Agr.Sc.
Technical Officer—L. J. Phillips, Q.D.D.M.
Technical Officer—W. Stern, B.Sc.Agr.
Technical Officer—W. Stahl.

Regional Survey, Canberra—
Research Officer—G. A. Stewart, B.Agr.Sc.
Research Officer—R. A. Perry, B.Sc.
Research Officer—J. Sleeman, B.Agr.Sc. (seconded from Division of Soils).
Technical Officer—M. Lazarides, Q.D.A.

Papua-New Guinea Resources Survey, Canberra—
Research Officer—S. J. Paterson, B.Sc.

20. Section of Mathematical Instruments.

(Head-quarters: University of Sydney.)

Officer-in-charge—Professor D. M. Myers, B.Sc., D.Sc.Eng.
Senior Research Officer—W. R. Blunden, B.Sc., B.E.
Research Officer—M. W. Allen, B.E.
Research Officer—C. B. Speedy, B.E. (attached from University of Sydney).
Technical Officer—R. J. Keith, B.E., A.S.T.C.

21. Section of Mathematical Statistics.

(Head-quarters: University of Adelaide.)

At Head-quarters, Adelaide—
Officer-in-charge—E. A. Cornish, D.Sc., B.Agr.Sc.
Research Officer—V. J. Bofinger, B.Sc.
Research Officer—A. G. L. Elliott, B.Sc.
Research Officer—K. P. Haydock, B.Sc.
Research Officer—A. T. James, M.Sc. (abroad).
Research Officer—P. F. May, B.Sc.Agr.
Research Officer—K. W. Morris, B.Sc.
Research Officer—Mrs. E. A. Remilton, B.A.
Research Officer—J. G. Sanderson, B.Sc.
Research Officer—G. N. Wilkinson, B.Sc.

At Division of Animal Health and Production, Sydney—
Senior Research Officer—Miss H. A. Newton Turner, B.Arch.
Research Officer—Miss M. C. McKevett, B.A.
Research Officer—Mrs. E. F. Turton, B.Sc.

At Division of Building Research, Highett, Victoria—
Research Officer—R. Birtwistle, B.Sc.

At Division of Food Preservation and Transport, Homebush, New South Wales—
Research Officer—G. G. Coote, B.A., B.Sc.

At Division of Forest Products, Melbourne—
Senior Research Officer—E. J. Williams, B.Com.
Technical Officer—Miss N. Ditchburne.

At Division of Plant Industry, Canberra—
Principal Research Officer—G. A. McIntyre, B.Sc., Dip.Ed.
Research Officer—Miss N. B. Hemingway, B.Sc.

At University of Western Australia, Perth—
Research Officer—N. S. Stenhouse, B.Sc.

22. Section of Meteorological Physics.

(Head-quarters: Graham-road, Highett, Victoria.)

Officer-in-charge—C. H. B. Priestley, M.A.
Principal Research Officer—W. C. Swinbank, B.Sc.
Principal Research Officer—E. L. Deacon, B.Sc.
Research Officer—I. C. McIlroy, B.Sc.
Research Officer—R. J. Taylor, B.Sc.
Research Officer—E. K. Webb, B.A., B.Sc.
Research Officer—F. K. Ball, B.Sc.
Research Officer—C. F. Barrett, M.Sc.
Research Officer—W. W. Moriarty, M.Sc.
Technical Officer—I. S. Groodin, Dip.Mat.
Technical Officer—D. E. Angus, B.Sc.
Technical Officer—A. J. Troup, B.Sc.
Technical Officer—D. R. Samuel, Dip.App.Sc.

23. Division of Metrology.

(Head-quarters: National Standards Laboratory at University of Sydney.)

Chief—N. A. Esserman, B.Sc.
Technical Secretary—N. H. Winters, B.E.
Principal Research Officer—C. A. Gladman, B.Sc.
Senior Research Officer—G. A. Bell, B.Sc.
Senior Research Officer—H. J. Ritter, Dr.rer.nat.-math.
Senior Research Officer—C. F. Bruce, M.Sc.
Research Officer—H. A. Ross, A.S.T.C.
Research Officer—R. H. Furniss, A.S.T.C.
Research Officer—J. A. Macinante, B.E.
Research Officer—W. A. F. Cuninghame, B.E.
Research Officer—Miss M. C. Dive, B.Sc.
Research Officer—Miss M. G. I. Pearce, M.Sc.
Research Officer—Miss P. M. Yelland.
Research Officer—R. J. Ellis, B.E.
Research Officer—Miss M. M. Douglas, B.Sc.
Research Officer—J. Waldersee, B.Sc.
Research Officer—N. J. C. Peres, B.Sc.
Research Officer—B. S. Thornton, B.Sc.
Research Officer—J. Rector, B.E., B.Sc.
Technical Officer—D. H. Fox.
Technical Officer—G. W. Gore, A.S.T.C.
Technical Officer—J. W. Bell.
Technical Officer—E. Grunwald.
Technical Officer—J. C. Kelly, B.Sc.
Technical Officer—E. J. Thwaite, B.Sc.
Technical Officer—I. F. Mayer, B.Sc.
Technical Officer—I. J. Somervaille, A.S.T.C.
Technical Officer—S. A. Dunk, A.S.T.C.
Technical Officer—O. Pain.

24. Mineragraphic Investigations.

(Head-quarters: University of Melbourne.)

Senior Principal Research Officer—F. L. Stillwell, D.Sc.
Senior Principal Research Officer—A. B. Edwards, D.Sc., Ph.D.
Research Officer—G. Baker, M.Sc.
Research Officer—J. McAndrew, B.Sc., Ph.D.
Technical Officer—G. C. Carlos.

25. National Standards Laboratory.

(The services shown hereunder are common to the Divisions of Metrology, Electrotechnology, and Physics, housed in the Laboratory.)

Clerical—
Chief Clerk—W. J. Gillespie, A.F.I.A., A.C.I.S.
Accountant—F. J. Whitty.

Library—
Librarian—Miss M. McKechnie, B.A.
Librarian—Miss J. M. Cook, B.A.
Librarian—Miss C. Gough.
Senior Assistant Librarian—Miss P. Feughelman, B.A.
Senior Assistant Librarian—Mrs. B. D. Holden.
Senior Assistant Librarian—Miss A. Benardos.
Senior Assistant Librarian—Miss E. V. Plummer.
Senior Assistant Librarian—Miss S. J. Walker.

Workshops—
Engineer-in-charge—J. Hanna.

Drawing Office—
Sectional Draughtsman—B. H. P. Cresswell, Dip.Mech.Eng.
Sectional Draughtsman—J. Coles.
Sectional Draughtsman—C. M. Williamson.
Draughtsman, Grade 2—R. Riches.
Draughtsman, Grade 2—R. Partridge.
Draughtsman, Grade 2—J. Weir.
Draughtsman, Grade 2—K. Apps, Dip.Mech.Eng.

26. Oenological Research.

(Head-quarters: Waite Agricultural Research Institute, Adelaide.)

Senior Research Officer—J. C. M. Fornachon, M.Sc., B.Ag.Sc.
Research Officer—B. C. Rankine, B.Sc.

27. Ore-dressing Investigations.

At University of Melbourne—
Officer-in-charge—Associate Professor H. H. Dunkin, B.Met.E.
Senior Research Officer—K. S. Blaskett, B.E.
Research Officer—S. B. Hudson, M.Sc.
Research Officer—J. T. Woodcock, B.Met.E., M.Eng.Sc.
Technical Officer—F. D. Drews.
Technical Officer—R. R. Lever.
Technical Officer—T. F. Wallace.

28. Section of Physical Metallurgy.

(Head-quarters—University of Melbourne.)

Officer-in-charge (honorary).—Professor J. Neill Greenwood, D.Sc., M.Met.E.
Senior Research Officer—H. W. Worner, M.Sc.
Research Officer—R. C. Gifkins, B.Sc.
Research Officer—A. E. Jenkins, M.Eng.Sc.
Technical Officer—J. A. Corbett.
Technical Officer—G. Boyd, A.M.T.C.

29. Division of Physics.

(Head-quarters: National Standards Laboratory at University of Sydney.)

Administration—
Chief—G. H. Briggs, D.Sc., Ph.D.
Technical Secretary—D. S. Woodward.

Heat—
Principal Research Officer—A. F. A. Harper, M.Sc.
Research Officer—W. R. G. Kemp, B.Sc.
Research Officer—R. G. Wylie, M.Sc.
Research Officer—G. K. White, M.Sc., D.Phil.
Research Officer—P. G. Klemens, M.Sc., D.Phil.
Research Officer—W. A. Caw, B.Sc.
Research Officer—Miss R. Scott, B.Sc.
Research Officer—N. H. Westwood, B.Sc.
Research Officer—A J. Mortlock, M.Sc.
Research Officer—J. Middlehurst, B.Sc.
Technical Officer—J. V. McAllan, B.Sc.
Technical Officer—J. K. Braithwaite, A.M.T.C.
Technical Officer—J. W. W. Smyth.

Light—
Principal Research Officer—R. G. Giovanelli, D.Sc.
Research Officer—W. H. Steel, B.A., B.Sc. (abroad).
Research Officer—K. A. Wright, B.Sc.
Research Officer—R. J. LeMesurier, B.Sc.
Research Officer—Associate Professor G. H. Godfrey, M.A., B.Sc. (part-time).
Technical Officer—W. J. Brown, A.S.T.C.
Technical Officer—D. G. Norton.
Technical Officer—Miss J. Ward.

olar Physics—
Research Officer—J. T. Jefferies, B.Sc.
lectronics—
Research Officer—A. F. Young, M.Sc.

30. Plant Fibre Section.

(Head-quarters: Graham-road, Highett, Victoria.)
Officer-in-charge—W. L. Greenhill, M.E.
Senior Research Officer—Miss J. F. Couchman, B.Sc.
Senior Research Officer—G. W. Lanigan, M.Sc.
Research Officer—K. Stiebris, D.Sc.
Research Officer—W. Shepherd, B.Sc., B.Ag.Sc.
Technical Officer—M. Tisdall, A.M.T.C.
Technical Officer—C. J. Brady, B.Ag.Sc.

31. Plant Genetics.

t Adelaide—
Senior Research Officer—B. Horowitz, D.Agr.Sc.
Oil Seeds Investigations—
Research Officer—R. E. Shapter.

32. Division of Plant Industry.

(Head-quarters: Canberra, Australian Capital Territory.)
Administration, Canberra—
Chief—O. H. Frankel, D.Sc., D.Agr.
Associate Chief—J. G. Davies, B.Sc., Ph.D.
Technical Secretary—A. Shavitsky, B.Agr.Sc.
Chief Clerk—K. J. Prowse (half-time).
Deputy Chief Clerk—D. W. Banyard (half-time).
General Services, Canberra—
Librarian—Miss J. Humphreys, B.A., Dip.Ed. (half-time).
Librarian—Miss J. Rosenberg, B.A. (half-time).
Technical Officer—J. Deans.
Technical Officer—J. Pomeroy.
Technical Officer—C. Wilson.
Group 1—Botany and Genetics—
Leader—O. H. Frankel, D.Sc., D.Agr.
Deputy Leader—C. Barnard, D.Sc.
Structural Botany, Canberra—
Principal Research Officer—C. Barnard, D.Sc.
Plant Introduction, Canberra—
Principal Research Officer—W. Hartley, B.A., Dip.Agr.
Research Officer—C. A. Neal-Smith, B.Agr.Sc., R.D.A.
Technical Officer—R. J. Williams, B.Sc.
Technical Officer—Miss D. E. Johns, B.Sc.
Technical Officer—R. Seton.
Herbarium, Canberra—
Research Officer—Miss N. T. Burbidge, M.Sc.
Plant Introduction, Queensland—
Senior Research Officer—J. F. Miles, B.Agr.Sc.
Technical Officer—R. B. Waite, Q.D.A.
Plant Introduction, Katherine, Northern Territory—
Technical Officer—A. E. Wynn.
Plant Introduction, Western Australia—
Senior Research Officer—E. T. Bailey, B.Sc.
Technical Officer—N. B. Gayfer, Dip. Agr.D.
Technical Officer—A. L. Rogers.
Plant Genetics, Canberra—
Principal Research Officer—E. M. Hutton, D.Sc., B.Agr.Sc.
Research Officer—R. D. Brock, B.Agr.Sc. (studentship abroad).
Research Officer—M. V. Carter, B.Agr.Sc.
Technical Officer—A. R. Peak, H.D.A.
Technical Officer—R. R. Rochford.
Technical Officer—J. W. Peak.
Technical Officer—J. D. Williams, D.D.A.
Microbiology, Canberra—
Principal Research Officer—D. R. Norris, D.Sc. (Agric.).
Research Officer—J. H. E. Mackay, B.Sc.Agr.
Research Officer—Miss K. Helms, B.Sc.
Research Officer—N. E. Walters, B.Sc. (abroad).
Technical Officer—J. Brockwell, D.D.A.
Technical Officer—Miss J. Friend, B.Sc.Agr.
Soil Microbiology, Canberra—
Research Officer—S. M. Bromfield, M.Agr.Sc. (studentship abroad).
Disease Control Investigations, Canberra—
Principal Research Officer—H. R. Angell, O.B.E., Ph.D.
Technical Officer—C. S. McKay, D.D.A.
Fruit Investigations, Hobart, Tasmania—
Principal Research Officer—D. Martin, M.Sc.
Research Officer—T. L. Lewis, B.Sc.
Technical Officer—J. Cerny, Ph.D.
Fruit Investigations, Stanthorpe, Queensland—
Principal Research Officer—L. A. Thomas, M.Sc.
Research Officer—R. C. Colbran, B.Agr.Sc.
Medicinal and Drug Plant Investigations, Canberra—
Senior Research Officer—K. L. Hills, M.Agr.Sc.
Technical Officer—P. I. Mortimer, B.Sc.
Technical Officer—D. R. Meyer.

Group 2—Chemistry and Physiology—
Leader—(vacant).
General Chemistry, Canberra—
Senior Research Officer—C. H. Williams, M.Sc.
Research Officer—A. Steinbergs, Nut.Chem.Univ. Riga.
Research Officer—D. J. David, B.Sc. (at Adelaide).
Technical Officer—K. Mayer, Q.D.A.
Plant Nutrition, Canberra—
Senior Research Officer—A. J. Anderson, B.Sc. (Agric.).
Research Officer—D. Spencer, B.Sc.
Research Officer—K. D. McLachlan, B.Sc.Agr., B.Comm.
Research Officer—J. F. Lonerogan (studentship abroad).
Research Officer—J. V. Possingham, B.Agr.Sc.
Plant Biochemistry, Canberra—
Research Officer—W. Bottomley, B.Sc., Ph.D. (abroad).
Tobacco Chemistry, Canberra—
Research Officer—R. J. Johanson, M.Sc.
Technical Officer—Mrs. D. H. Encel, B.Sc.
Plant Physiology, Adelaide, South Australia—
Principal Research Officer—L. A. T. Ballard, Ph.D., M.Ag.Sc.
Research Officer—J. Zwar, M.Agr.Sc.
Research Officer—N. P. Kefford, M.Sc (studentship abroad).
Technical Officer—R. Fawcett, R.D.A.
Plant Physiology, Canberra—
Research Officer—J. Calvert, D.Sc.
Plant Physiology, Griffith, New South Wales—
Senior Research Officer—R. F. Williams, M.Sc.
Plant Toxicology, Canberra—
Senior Research Officer—C. G. Greenham, M.Sc. (abroad).
Research Officer—P. Goldacre, M.Sc. (studentship abroad).
Technical Officer—C. V. de Plater, A.I.M.R.E.

Group 3—Agrostology and Agronomy (including Regional Laboratories)—
Leader—J. G. Davies, B.Sc., Ph.D.
Deputy Leader (Senior Principal Research Officer)—C. M. Donald, M.Sc.Agr.

At Canberra—

Dickson Experiment Station—

Senior Research Officer—W. D. Andrew, M.Agr.Sc.
Research Officer—W. M. Willoughby, B.Sc.Agr.
Senior Technical Officer—L. Sharp, D.D.A.
Technical Officer—J. A. Redpath.
Technical Officer—R. T. Milligan, D.D.A.
Technical Officer—V. H. Southwell.
Technical Officer—A. Axelsen, Q.D.A.H.

Ecology—

Senior Research Officer—R. M. Moore, M.Sc.Agr.
Research Officer—C. W. E. Moore, B.Agr.Sc.
Research Officer—L. F. Meyers, B.Agr.Sc.
Research Officer—E. F. Biddiscombe, B.Sc. (Agric.).
Technical Officer—J. A. Robertson, Q.D.D.M.
Technical Officer—J. A. Bull.

Tobacco—

Principal Research Officer—A. V. Hill, M.Agr.Sc.
Research Officer—D. C. Wark, M.Ag.Sc.
Technical Officer—M. Mandryk, B.Sc.Agr.

At Institute of Agriculture, Perth—

Senior Research Officer—R. C. Rossiter, D.Sc., B.Sc. (Agric.).
Research Officer—P. G. Ozanne, B.Sc. (Agric.).
Technical Officer—R. J. Pack, Q.D.A.

At "Glen Lossie" Field Station, Kojonup, Western Australia—

Research Officer—E. Watson, B.Sc. (Agric.).
Senior Technical Officer—J. Tudor.
Technical Officer—P. Lapins.
Technical Officer—J. Beresford, Dip.Agr.D.

At Regional Pastoral Laboratory, Armidale, New South Wales—

Agrostology and Agronomy—

Senior Research Officer—R. Roe, B.Sc. (Agric.).
Research Officer—K. Spencer, B.Sc.Agr.
Research Officer—E. J. Hilder, B.Sc (Agric.).
Research Officer—J. E. Begg, B.Sc.Agr.
Technical Officer—J. R. Freney, B.Sc.
Technical Officer—V. J. Wolfe, Q.D.A.
Technical Officer—Miss J. A. Stubbs, B.Sc.Agr.
Technical Officer—B. E. Mottershead, B.Sc.

Ecology—

Research Officer—R. W. Jessup, M.Sc.
Research Officer—A. A. Holland, M.Sc.
Technical Officer—F. R. Gnauck, B.Sc.

At Mitchell Laboratory, Trangie, New South Wales—

Technical Officer—R. J. Hutchings, D.D.A.

At Regional Laboratory, Deniliquin, New South Wales—

Principal Research Officer—R. W. Prunster, B.Sc. (Agric.).
Research Officer—J. R. Philip, B.C.E.
Research Officer—O. B. Williams, B.Agr.Sc.
Research Officer—K. P. J. Barley, B.Agr.Sc.
Technical Officer—J. W. Birch, D.D.A.
Technical Officer—G. J. Wright, D.D.A.
Technical Officer—F. Arndt, Q.D.A.

At Falkiner Memorial Field Station, Deniliquin, New South Wales—

Technical Officer—G. A. Vasey, D.D.A.

At Irrigation Research Station, Griffith, New South Wales—

Ecology—

Research Officer—E. Levi, M.Sc.

At Plant and Soils Regional Laboratory, Brisbane, Queensland—

Principal Research Officer—T. B. Paltridge, B.Sc. (abroad).

Agronomy—

Senior Research Officer—W. W. Bryan, M.Sc.Agr.
Research Officer—S. G. Gray, B.Sc.Agr.
Technical Officer—J. Conroy, Q.D.A.

Cattle Pastures—

Senior Research Officer—N. H. Shaw, B.Agr.Sc.
Technical Officer—F. W. Elich, Dip.Col.Agr.

Plant Nutrition—

Research Officer—C. S. Andrew, B.Ag.Sc.
Technical Officer—W. H. J. Pieters, Dip.Col.Agr.

Plant Chemistry—

Research Officer—E. H. Kipps, B.Sc.

Ecology—

Research Officer—J. E. Coaldrake, B.Sc.
Research Officer—L. J. Webb, M.Sc.
Technical Officer—J. G. Tracey, Q.D.A.

At Cooper Laboratory, Lawes, Queensland—

Research Officer—W. G. Robertson, B.Ag.Sc.
Research Officer—W. J. Bisset, B.Ag.Sc.
Technical Officer—G. A. Taylor, Q.D.A.
Technical Officer—R. Milford, B.Agr.Sc., Q.D.A.
Technical Officer—H. J. Kiers, Dip.Col.Agr.
Technical Officer—A. M. Sanders, Dip.Col.Agr.

At Ayr, Queensland—

Tobacco—

Research Officer—W. J. Lovett, B.Agr.Sc.
Technical Officer—J. D. Fitzsimon, Q.D.H.
Technical Officer—J. B. Murday, Q.D.A.

33. RADIO RESEARCH BOARD.

(Head-quarters: University of Sydney.)

At Canberra—

Chief Scientific Officer—D. F. Martyn, D.Sc., Ph.D., A.R.C.Sc., F.R.S.
Research Officer—E. T. Robinson, B.Sc.

At Sydney—

Principal Research Officer—G. H. Munro, D.Sc.
Senior Research Officer—W. L. Price, B.Sc. (part-time).
Research Officer—J. A. Harvey, B.Sc.
Research Officer—L. Heisler, B.Sc.
Technical Officer—R. O. Errey.
Technical Officer—Miss B. Hardwick.
Technical Officer—H. P. Hirschl, A.S.T.C.
Technical Officer—R. B. White, B.E.

34. DIVISION OF RADIOPHYSICS.

(Head-quarters: University of Sydney.)

Chief—E. G. Bowen, O.B.E., M.Sc., Ph.D.
Assistant Chief—J. L. Pawsey, M.Sc., Ph.D.
Technical Secretary—A. J. Higgs, B.Sc. (abroad).
Acting Technical Secretary—L. L. McCready, B.Sc., B.E.

Rain and Cloud Physics—

Senior Research Officer—J. Warner, B.Sc., B.E.
Senior Research Officer—E. J. Smith, M.B.E., B.Sc.(Eng.).
Senior Research Officer—P. Squires, M.A.
Research Officer—E. E. Adderley, B.Sc.
Research Officer—N. R. Labrum, B.Sc.
Research Officer—H. L. Humphries, B.Sc., B.E., B.Ec.
Research Officer—R. S. Styles, B.Sc., B.E.
Research Officer—S. Twomey, M.Sc.
Research Officer—J. W. Telford, B.Sc.
Senior Technical Officer—G. T. Miles.
Technical Officer—T. D. Newnham.
Technical Officer—F. W. Campbell.
Technical Officer—L. F. Clague.
Technical Officer—K. J. Heffernan.
Technical Officer—K. A. Davidson.
Technical Officer—D. C. Dunn.
Technical Officer—N. S. Thorndike.
Technical Officer—R. T. H. Bowles, A.M.T.C.

Radio Astronomy—

Principal Research Officer—J. H. Piddington, M.Sc., B.E., Ph.D.
Senior Research Officer—W. N. Christiansen, M.Sc.
Senior Research Officer—F. J. Kerr, M.Sc., M.A.
Research Officer—J. G. Bolton, B.A.
Research Officer—B. Y. Mills, B.Sc., M.E.
Research Officer—R. N. Bracewell, B.Sc., B.E., Ph.D.
Research Officer—S. F. Smerd, B.Sc.
Research Officer—J. P. Wild, M.A.
Research Officer—C. A. Shain, B.Sc.
Research Officer—F. F. Gardner, B.Sc., B.E.
Research Officer—L. W. Davies, B.Sc., D.Phil.
Research Officer—R. X. McGee, B.Sc.
Research Officer—R. D. Davies, B.Sc.
Research Officer—J. A. Warburton, B.Sc.
Research Officer—E. R. Hill, M.Sc.
Technical Officer—J. V. Hindman.
Technical Officer—C. S. Higgins.
Technical Officer—G. J. Stanley, A.S.T.C.
Technical Officer—J. D. Murray, B.Sc.(Eng.).
Technical Officer—A. G. Little, A.S.T.C.
Technical Officer—O. B. Slee.
Technical Officer—R. S. Joseph, A.S.T.C.
Technical Officer—H. R. Harant, A.S.T.C.

Mathematical Investigations—

Senior Research Officer—T. Pearcey, B.Sc.
Senior Research Officer—M. Beard, B.Sc., B.E.
Senior Research Officer—B. F. C. Cooper, B.Sc., B.E.
Research Officer—Miss M. A. Adamson, B.A., Dip.Ed.
Research Officer—R. D. Ryan, B.Sc., B.E.
Research Officer—G. W. Hill, B.Sc.
Research Officer—B. J. J. McHugh, B.Sc.
Research Officer—O. M. Phillips, B.Sc.
Technical Officer—F. C. Tonking, A.S.T.C.
Technical Officer—R. C. Baker.
Technical Officer—J. Algie, A.S.T.C.

Radio Navigation—

Senior Research Officer—H. C. Minnett, B.Sc., B.E.
Research Officer—D. E. Yabsley, B.Sc., B.E.
Research Officer—G. A. Day.
Research Officer—M. Strohfeldt, M.Sc.
Senior Technical Officer—K. V. Sheridan (on study leave).
Senior Technical Officer—P. T. Hedges, A.S.T.C.
Technical Officer—L. A. Wade, A.S.T.C.
Technical Officer—S. A. Pett.
Technical Officer—C. F. Attwood.

Engineering Services—

Chief Draughtsman—F. M. Carter.
Senior Technical Officer—H. Byers.
Senior Technical Officer—G. A. Wells, A.S.T.C.
Technical Officer—K. A. McAlister, A.S.T.C.
Technical Officer—F. C. James.
Draughtsman, Grade 2—H. F. Peddie, Dip.Elec. Eng.
Draughtsman, Grade 2—J. R. Morris.
Draughtsman, Grade 2—D. E. Brown, Dip.Radio Eng.

Officers Abroad—

Research Officer—E. K. Bigg, M.Sc.
Research Officer—J. A. Roberts, M.Sc.
Research Officer—R. F. Mullaly, B.Sc.

35. Division of Soils.

(Head-quarters: Waite Agricultural Research Institute, Adelaide, South Australia.)

At Adelaide—

Administration—

Chief—J. K. Taylor, B.A., M.Sc., B.Sc.Agr.
Technical Secretary—A. L. C. Davidson, B.Sc., Ph.D.

Soil Survey and Pedology Section—

Senior Principal Research Officer—C. G. Stephens, D.Sc.
Research Officer—K. H. Northcote, B.Ag.Sc.
Research Officer—G. Blackburn, B.Ag.Sc.
Research Officer—E. A. Jackson, B.Ag.Sc.
Research Officer—C. B. Wells, B.Ag.Sc.
Research Officer—W. H. Litchfield, B.Sc.Agr.
Cartographer—P. D. Hooper.

Soil Chemistry Section—

Principal Chemist—C. S. Piper, D.Sc.
Senior Research Officer—A. C. Oertel, M.Sc.
Research Officer—J. T. Hutton, B.Sc., A.S.A.S.M. (abroad).
Research Officer—H. C. T. Stace, B.Sc.
Research Officer—B. M. Tucker, B.Sc.
Research Officer—R. S. Beckwith, B.Sc.
Research Officer—M. Raupach, B.Sc.
Technical Officer—A. D. Haldane, B.Sc.
Technical Officer—A. R. P. Clarke, A.S.A.S.M.
Technical Officer—R. M. McKenzie, A.S.A.S.M.
Technical Officer—R. D. Bond, A.S.A.S.M.

Soil Physics and Mechanics Section—

Senior Principal Research Officer—T. J. Marshall, M.Ag.Sc., Ph.D.
Senior Research Officer—G. D. Aitchison, M.E. (at University of Melbourne).
Research Officer—K. Norrish, M.Sc. (abroad).
Research Officer—J. P. Quirk, B.Sc.Agr. (abroad).
Research Officer—C. G. Gurr, B.Sc.
Research Officer—J. W. Holmes, B.Sc.
Research Officer—E. W. Radoslovich, M.Sc.
Research Officer—D. S. McIntyre, M.Sc.
Technical Officer—A. W. Palm.

Soil Microbiology Section—

Principal Research Officer—R. J. Swaby, M.Sc., M.Ag.Sc., Ph.D.
Research Officer—J. R. Harris, M.Sc.
Technical Officer—Mrs. B. I. Passey, B.Sc.

At Brisbane—

Soil Survey and Pedology—

Senior Research Officer—G. D. Hubble, B.Ag.Sc. (abroad).
Research Officer—G. G. Beckman, B.Sc.
Technical Officer—C. H. Thompson, Q.D.A.

Soil Physics—

Research Officer—G. B. Stirk, B.Sc.

Soil Chemistry—

Research Officer—A. E. Martin, B.Sc.
Research Officer—J. E. Cox, B.Sc.
Technical Officer—R. Reeve, D.I.C.

At Canberra—

Soil Survey and Pedology—

Research Officer—R. Brewer, B.Sc.
Research Officer—D. C. van Dijk, l.i., Dr. rer. nat.
Research Officer—J. R. Sleeman, B.Ag.Sc. (seconded to Land Research and Regional Survey Section).
Research Officer—H. M. Churchward, B.Sc.Agr.

At Deniliquin—

Soil Survey and Pedology—

Senior Research Officer—B. E. Butler, B.Agr.Sc.

At Hobart—
Soil Survey and Pedology—
Research Officer—K. D. Nicolls, B.Ag.Sc., B.Sc.
Research Officer—G. M. Dimmock, B.Sc.
Research Officer—J. Loveday, B.Ag.Sc.
Soil Chemistry—
Technical Officer—A. M. Graley, B.Sc.

At Perth—
Soil Survey and Pedology—
Senior Research Officer—R. Smith, D.Sc. (Agr.).
Research Officer—L. W. Pym, B.Sc.(Agr.).
Research Officer—T. Poutsma, B.Sc.(Agr.).
Research Officer—W. M. McArthur, B.Sc.
Soil Chemistry—
Research Officer—A. G. Turton, B.Sc.

36. Division of Tribophysics.

(Head-quarters: University of Melbourne.)
Chief—W. Boas, D.Ing., M.Sc.
Senior Research Officer—M. F. R. Mulcahy, D.Phil., M.Sc., A.G.Inst.Tech.
Research Officer—J. K. Mackenzie, Ph.D., B.A., B.Sc.
Research Officer—A. J. W. Moore, Ph.D., B.Sc. (on leave).
Research Officer—R. G. Vines, M.Sc.
Research Officer—J. S. Bowles, M.Sc.
Research Officer—M. E. Hargreaves, Ph.D., B.Met.E.
Research Officer—D. Michell, B.E.E.
Research Officer—M. J. Ridge, M.Sc.
Research Officer—G. W. West, B.E.E., B.Sc.
Research Officer—L. M. Clarebrough, B.Met.E., M.Eng.Sc. (abroad).
Research Officer—B. D. Cuming, M.Sc. (abroad).
Research Officer—A. J. Davis, B.Eng.
Research Officer—S. R. McDonald, M.Sc.
Research Officer—J. F. Nicholas, B.A., B.Sc.
Research Officer—G. J. Ogilvie, Ph.D., B.Met. E., M.Eng.Sc.
Research Officer—J. V. Sanders, Ph.D., B.Sc.
Research Officer—Mrs. H. M. C. Sosnowsky, Ph.D.
Research Officer—Mrs. A. M. Swan, Ph.D., B.Sc.
Research Officer—J. A. Spink, B.Sc.
Research Officer—I. C. Watt, M.Sc.
Research Officer—J. E. Young, Ph.D.
Technical Officer—H. W. Hutchinson.
Technical Officer—G. Brinson, B.Sc.
Technical Officer—F. H. Hay.
Technical Officer—D. J. Norris.
Technical Officer—G. R. Perger, F.M.T.C.
Technical Officer—J. J. Batten, B.Sc.
Technical Officer—L. A. Bennett, B.Sc.
Technical Officer—R. W. Coventry, B.Sc.
Technical Officer—R. G. Sherwood, A.M.T.C.
Technical Officer—W. J. McG. Tegart, B.Sc., A.M.T.C.

37. Wildlife Survey Section.

(Head-quarters: Canberra, Australian Capital Territory.)
Officer-in-charge—F. N. Ratcliffe, B.A.
Sectional Secretary—F. N. Robinson, B.A.
Research Officer—J. le G. Brereton, B.Sc. (on leave abroad).
Research Officer—W. E. Poole, B.Sc.
Technical Officer—J. H. Calaby.

At Perth—
Senior Research Officer—D. L. Serventy, B.Sc., Ph.D.

At Albury, New South Wales—
Research Officer—B. V. Fennessy, B.Agr.Sc.
Research Officer—K. Myers, B.Sc.

38. Wool Textile Research Laboratories.

Senior Officer-in-charge—F. G. Lennox, D.Sc.
At Wool Textile Research Laboratory, Melbourne—
Biochemistry Unit, 343 Royal-parade, Parkville, Victoria—
Officer-in-charge—F. G. Lennox, D.Sc.
Laboratory Secretary—C. Garrow, Dip.Pub. Admin., A.F.I.A.
Senior Research Officer—H. Lindley, B.A., Ph.D.
Senior Research Officer—W. G. Crewther, M.Sc.
Research Officer—T. A. Pressley, B.Sc.
Research Officer—J. M. Gillespie, M.Sc.
Research Officer—M. A. Jermyn, M.Sc., Ph.D.
Research Officer—S. J. Leach, B.Sc.Tech., Ph.D.
Research Officer—J. M. Swan, B.Sc., Ph.D.
Research Officer—E. F. Woods, M.Sc., A.M.T.C. (abroad).
Research Officer—J. A. Friend, M.Sc., Ph.D.
Research Officer—D. H. Simmonds, M.Sc., Ph.D.
Research Officer—I. J. O'Donnell, M.Sc.
Research Officer—R. Thomas, B.Sc., Ph.D.
Research Officer—G. E. Rogers, M.Sc.
Technical Officer—Mrs. H. M. Forss, A.M.T.C.
Senior Assistant Librarian—Miss N. T. Murphy.
Solvent Degreasing Investigations, Maribyrnong—
Principal Research Officer—E. J. Drake.
At Wool Textile Research Laboratory, Sydney—
Physics and Engineering Unit, "The Hermitage", 338 Blaxland-road, Ryde, New South Wales—
Officer-in-charge—V. D. Burgmann, B.Sc., B.E.
Technical Secretary—I. J. W. Bisset, M.Sc.
Senior Research Officer—J. G. Downes, B.Sc.
Research Officer—M. Feughelman, B.Sc.
Research Officer—I. M. Stuart, B.Sc.
Research Officer—Miss V. Laws, M.Sc.
Research Officer—Mrs. K. R. Makinson, B.A. (abroad).
Technical Officer—J. E. Thompson.
Technical Officer—Miss J. C. Griffith, B.Sc., A.S.T.C.
Technical Officer—A. G. Stutter, B.Sc.
Senior Assistant Librarian—Miss E. E. Shoebridge, B.A.
At Wool Textile Research Laboratory, Geelong—
Officer-in-charge—M. Lipson, B.Sc., Ph.D.
Technical Secretary and Textile Liaison Officer—N. A. Whiffen, F.S.T.C. (seconded).
Senior Research Officer—D. L. C. Jackson, B.Sc.
Senior Research Officer—G. W. Walls, B.Sc.
Research Officer—J. Delmenico, B.Sc.
Research Officer—N. K. Boardman, M.Sc. (abroad).
Research Officer—J. H. Bradbury, M.Sc (abroad).
Research Officer—D. S. Taylor, B.A., B.Sc. (abroad).
Research Officer—C. H. Nicholls, B.Sc. (abroad).
Research Officer—J. R. McPhee. B.Sc.
Technical Officer—J. F. Sinclair.
Technical Officer—Miss R. J. Hope, A.G.Inst. Tech.
Technical Officer—A. Gray, B.Sc. (abroad).
Technical Officer—G. C. West, Dipl.Text.Ind.
Technical Officer—A. Backwell, Dipl.Text.Chem.
Technical Officer—P. Strutt, B.Sc.
Senior Assistant Librarian—Miss R. Andrews.

XXXIV. PUBLISHED PAPERS.

The following papers have been published during the year:—

1. Division of Animal Health and Production.

Alexander, G., *and* Watson, R. H. (1951).—The assay of oestrogenic activity of *Trifolium subterraneum* L. by increase in uterine weight in the spayed guinea pig. I. Characteristics of the dose-response relationship. *Aust. J. Agric. Res.* **2: 457-79.**

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Austin, C. R. (1951).—The formation, growth, and conjugation of the pronuclei in the rat egg. *J. R. Micr. Soc.* 71:295-306.

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Dick, A. T., *and* Bingley, J. B. (1951).—Further observations on the determination of molybdenum in plant and animal tissue. *Aust. J. Exp. Biol. Med. Sci.* 29:459-62.

Esserman, Helene B., *and* Sambell, Pauline M. (1951).—The uptake of radio-active phosphate by nematode parasites and by tissues of the sheep. *Aust. J. Sci. Res.* B 4:575-80.

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Franklin, M. C., *with the technical assistance of* Sutton, P. B. (1952).—Maintenance rations for Merino sheep. I. A comparative study of daily and weekly feeding on rations containing high proportions of wheat and several proportions of roughage to concentrate. *Aust. J. Agric. Res.* 3:168-86.

Gordon, H. McL. (1952).—Anthelmintics and the control of helminth diseases of sheep. Rep. 14th Int. Vet. Congr. 2:71-80.

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Gregory, T. S. (1952).—Diagnosis and control of bovine tuberculosis in the Australian environment. Rep. 14th Int. Vet. Congr. 2:207-11.

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Campbell, W. G.,[‡] Frahn, J. L., Hirst, E. L.,[§] Packman, D. F.,[‡] *and* Percival, E. G. V.[§] (1951).—Wood starches. Part I. *J. Chem. Soc.* 1951: 3489-98.

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[†] Western Australian Department of Agriculture; now at C.S.I.R.O. McMaster Animal Health Laboratory, Glebe, New South Wales.

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Blakey, F. A. (1951).—Discussion (Gedanken eines Praktikers zur Plastizitats-theorie im Stahlbetonbau, A. Freitag) *Beton u. Stahlbetonb.* 46 : 263.

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XXXV. FINANCE.

1. Expenditure.

The statement of expenditure from July 1, 1951, to June 30, 1952, is as follows:—

	£	£	£
(*a*) Salaries and contingencies			289,211*
(*b*) Investigations—			
(i) Animal Health and Production Problems		380,900	
Less contributions from—			
Wool Industry Fund	9,809		
Wool Research Trust Account	113,008		
Commonwealth Bank	2,500		
George Aitken Pastoral Research Trust	500		
Australian Dairy Produce Board	2,000		
Australian Meat Board	1,960		
Australian Wool Board (balance of old grants)	16		
Ian McMaster Bequest	1,888		
Alexander Fraser Memorial Fund	225		
Burdekin Bequest (drought feeding)	1,560		
Revenue Funds—			
Regional Pastoral Laboratory, Armidale	20,799		
Burdekin Bequest	400		
Poultry Breeding	9,531		
Vaccine	4,130		
Contagious Pleuropneumonia	2,554		
Tooradin Field Station	1,000		
Parasitology—McMaster Laboratory	167		
Oestrus	1,967		
Toxaemic Jaundice—Barooga	686		
Toxaemic Jaundice—Parkville	200		
Mastitis	4,273		
McMaster Field Station	5,576		
Gilruth Plains Field Station	24,750		
Gilruth Plains Reserve	481		
Cobram Field Station	518		
		210,498	
			170,402
(ii) Biochemistry and General Nutrition Problems		78,953	
Less contributions from—			
Wool Research Trust Account	28,115		
Revenue Fund—Nutrition Laboratory	2,753		
		30,868	
			48,085
(iii) Plant Problems—Division of Plant Industry		331,902	
Less contributions from—			
West Australian Golf Association	43*Cr.*		
Wool Industry Fund	308		
Wool Research Trust Account	50,539		
Revenue Funds—			
Plant Industry	2,743		
Glen Lossie Field Station	2,052		
Deniliquin Field Station	531		
		56,130	
			275,772
(iv) Entomology Problems		117,703	
Less contributions from—			
Australian Meat Board	2,119		
		2,119	
			115,584
(v) Soils and Irrigation Problems of Irrigation Settlements—			
(*a*) Citricultural—Research Station, Griffith		55,776	
Less contributions from—			
New South Wales Water Conservation and Irrigation Commission	2,000		
Revenue Fund—Griffith Research Station	1,149		
		3,149	
			52,627
(*b*) Viticultural—Research Station, Merbein		41,290	
Less contributions from—			
Dried Fruits Control Board	1,600		
Mildura Co-op. Fruit Company	250		
Irymple Packing Company	250		
Red Cliffs Co-op. Fruit Company	250		
Aurora Packing Company	250		
Co-op. Dried Fruit Sales Limited	250		
Revenue Fund—			
Merbein Station	2,954		
Nyah-Woorinen Enquiry Committee	27		
		5,831	
			35,459
			88,086
(vi) Soils Problems		101,036	
			101,036
Unapportioned overseas expenditure on Soils and Irrigation Investigations			700

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* The main items of expenditure under this heading are salaries of the Administrative Staff at the Organization's Head Office; salaries and expenses of officers at the Liaison Offices in London and Washington; staff and upkeep of State Committees; travelling expenses of Head Office Staff; and printing and general office expenditure.

	£	£	£
(vii) Food Preservation and Transport Problems		135,563	
Less contributions from—			
Commonwealth Bank	1,000		
New South Wales Department of Agriculture	1,616		
Metropolitan Meat Industry Commission	500		
Queensland Meat Industry Board	850		
Australian Meat Board	1,125		
Australian Egg Board	750		
Batlow Packing Company	172		
William Angliss Ltd.	38		
Revenue Funds—			
Food Preservation	280		
Fruit Juices	28		
		6,359	
			129,204
(viii) Forest Products Problems		196,545	
Less contributions from—			
Australian Paper Manufacturers Limited	500		
Associated Pulp and Paper Mills Limited	500		
Australian Newsprint Mills	500		
New Zealand Forest Products Limited	250		
Revenue Fund—Forest Products	3,908		
		5,658	
			190,887
(ix) Mining and Metallurgy		18,923	
Less contributions from—			
Australian Institute of Mining and Metallurgy	500		
		500	
			18,423
(x) Radio Research		26,708	
Less contributions from—			
Postmaster-General's Department	6,250		
Departments of Army, Navy, and Air	12,500		
		18,750	
			7,958
(xi) Research Services		70,974	
Less contributions from—			
Wool Research Trust Account	3,056		
Australian Dried Fruits Association	500		
		3,556	
			67,418
(xii) Industrial Chemistry		251,981	
Less contributions from—			
National Gas Association	600		
Cement and Concrete Association	750		
Revenue Fund—Microanalysis	1,276		
		2,626	
			249,355
(xiii) Fisheries Investigations		145,093	
Less contributions from—			
New South Wales Government	250		
Revenue Fund—Fisheries	932		
		1,182	
			143,911
(xiv) Mathematical Statistics			30,885
(xv) National Standards Laboratory			320,516
(xvi) Tribophysics			49,148
(xvii) Building Research			102,041
(xviii) Plant Fibre Research			28,980
(xix) Radiophysics Research			203,292
(xx) Metallurgical Research			6,361
(xxi) Nuclear Energy Research			48,553
(xxii) Meteorological Physics			32,905
(xxiii) Dairy Research			24,797
(xxiv) Wool Textile Research		177,010	
Less contributions from—			
Wool Research Trust Account	144.114		
Wool Industry Fund	29,984		
Department of Defence	1,000		
		175,098	
			1,912
(xxv) Fuel Research			89,372
(xxvi) Wildlife Survey		21,692	
Less contributions from—			
George Aitken Pastoral Research Trust	1,375		
Wool Research Trust Account	9,688		
Wool Industry Fund	942		
		12,005	
			9,687
(xxvii) Land Research and Regional Survey		37,305	
Less contributions from—			
Department of National Development	4,068		
Department of Territories	1,453		
		5,521	
			31,784
(xxviii) Genetics		13,342	
Less contributions from—			
Wool Research Trust Account	4,311		
Commonwealth Bank	144		
		4,455	
			8,887

	£	£	£
(xxix) Miscellaneous—			
(a) Biophysical Research		1,455	
(b) Oenological Research		3,690	
(c) Architectural Section		6,907	
(d) Various		2,861	
		14,913	
Less contributions from—			
Australian Wine Board	1,845		
Science and Industry Endowment Fund	215		
		2,060	
			12,853
(xxx) Unforeseen and Urgent—			
Total of Item (b)—Investigations			2,608,794
(c) Grants—			
(i) Research Associations—			
Leather Research Association	5,000		
Bread Research Institute	5,000		
		10,000	
(ii) Overseas Research Studentships		31,473	
		41,473	
Less contributions from—			
Wool Research Trust Account	10,095		
Science and Industry Endowment Fund	1,776		
		11,871	
			29,602
Total Salaries and Contingencies, Investigations and Grants			2,927,607

2. CONTRIBUTIONS AND DONATIONS.

The following statement shows the receipts and disbursements during the year 1951-52 of the funds provided by outside bodies and recorded in the special account entitled "The Specific Research Fund" (formerly "The Specific Purposes Trust Account"):—

	Receipts 1951-52 and balances brought forward from 1950-51.	Expenditure 1951-52.
	£	£
Wool Industry Fund Account	322,675	292,046*
Commonwealth Bank (Animal Health and Production, Food Preservation and Transport, and Genetics Investigations)	4,737	3,643
Australian Wool Board (Animal Health and Production Investigations—Sheep Research	1,625	16
Australian Dairy Produce Board (Mastitis Investigations)	2,000	2,000
George Aitken Pastoral Research Trust (Animal Health and Production Investigations)	1.000	500
Australian Meat Board (Toxaemic Jaundice Investigations, Barooga, New South Wales)	1,000	1,000
Australian Meat Board (Caseous Lymphadenitis Investigations—Animal Health and Production)	412	..
Australian Meat Board (Beef Cattle Research)	2,165	183A
Australian Meat Board (Bovine Pleuropneumonia Investigations)	823	800
Alexander Fraser Memorial Fund	225	225
C.P.P. Fairbairn (Animal Health and Production Investigations—Foot-rot Control)	30	..
Estate of the late Captain Ian McMaster (Animal Health and Production Investigations)	2,396	2,396B
West Australian Golf Association (Plant Industry Investigations)	50	*Cr.* 1C
Department of National Development — Northern Australia Regional Survey (Division of Plant Industry)	3,436	3,436
Department of National Development — Kimberley Research Station	632	632
United Graziers' Association of Queensland—Buffalo Fly and Cattle Tick Investigations (Entomology)	172	
Australian Meat Board—Colloidal Dispersions Investigations (Entomology)	2,364	2,119

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* For details of expenditure *see* page 172.

A. Includes £23 on account of 1950-51 expenditure.

B. Includes £509 on account of 1950-51 expenditure.

C. Represents expenditure incurred during 1951-52 and adjustment of incorrect debits in respect of 1950-51.

	Receipts 1951-52 and balances brought forward from 1950-51.	Expenditure 1951-52.
	£	£
Burdekin Bequest (Drought Feeding Investigations)	1,937	1,937D
New South Wales Water Conservation and Irrigation Commission (Maintenance of Griffith Research Station)	2,000	2.000
Mildura Co-op. Fruit Co. (Dried Vine Fruits Investigations, Merbein)	298	250
Irymple Packing Co. (Dried Vine Fruits Investigations, Merbein)	298	250
Red Cliffs Co-op. Fruit Co (Dried Vine Fruits Investigations, Merbein)	298	250
Aurora Packing Company (Dried Vine Fruits Investigations, Merbein)	298	250
Co-op. Dried Fruit Sales Ltd. (Dried Vine Fruit Investigations, Merbein)	298	250
Dried Fruits Control Board (Dried Fruits Investigations)	1,600	1,600
Nyah-Woorinen Dried Fruits Inquiry Committee (Dried Fruits Investigations)	453	27
Australian Dried Fruits Association (Packing House Methods Investigations)	1,000	500
Australian Meat Board (Meat Investigations)	500	500E
Metropolitan Meat Industry Commissioners of New South Wales (Meat Investigations)	500	500
Queensland Meat Industry Board (Meat Investigations)	850	850
New South Wales Department of Agriculture (Food Investigations)	1,000	1,000
Vita Food Supply Co. (Food Investigations)	105	..
W. Angliss Ltd (Division of Food Preservation and Transport)	488	38
Cottees Passiona Ltd (Food Investigations)	50	..
L. Berger and Sons (Division of Food Preservation and Transport)	100	..
Batlow Packing House Co-op. Ltd. (Division of Food Preservation and Transport—Fruit Juice Investigations)	550	172
Various Contributors (Division of Food Preservation and Transport—Fruit Juice Investigations)	28	28
Australian Meat Board (Division of Food Preservation and Transport — Physiological Investigations)	750	750

D. Includes £377 on account of 1950-51 expenditure.

E. Includes £125 on account of 1950-51 expenditure.

	Receipts 1951-52 and balances brought forward from 1950-51.	Expenditure 1951-52.
	£	£
Australian Egg Board (Division of Food Preservation and Transport—Egg Investigations)	750	750
New South Wales Department of Agriculture—Quick Freezing of Fruit and Vegetables (Division of Food Preservation and Transport)	834	616
Australian Paper Manufacturers Ltd. (Paper Pulp Investigations)	500	500
Australian Newsprint Mills (Paper Pulp Investigations)	1,000	1,000F
Associated Pulp and Paper Mills Ltd. (Paper Pulp Investigations)	500	500
New Zealand Forest Products Ltd. (Paper Pulp Investigations)	500	500G
Sundry Contributors (Forest Products Investigations)	4,173	3,908
Miscellaneous Contributors (Division of Forest Products—Timber Seasoning Work)	10	..
Miscellaneous Contributors (Division of Forest Products—Veneer and Gluing Work)	8	..
Victorian Railways—High Pressure Test—Railway Sleepers (Division of Forest Products)	1,180	..
Australian Institute of Mining and Metallurgy (Mineragraphic Investigations)	500	500
Postmaster-General's Department (Radio Research)	6,250	6,250
Departments of Army, Navy, and Air (Radio Research)	12,500	12,500
Drug Houses of Australia (Division of Fisheries—Agar Production)	25	..
Miscellaneous Contributors (Division of Industrial Chemistry)	691	..
Commonwealth Fertilizers and Chemicals (Industrial Chemistry)	300	..
Department of Supply (Textile Degradation Investigations)	2,000	2,000H
National Gas Association (Gas Investigations — Industrial Chemistry)	1,933	600
New South Wales Government (Fisheries Investigations)	500	500I
Australian Cement Manufacturers (Cement Investigations—Industrial Chemistry/Soils)	750	750
Apple and Pear Board—Thrips Investigations	77	..
Sundry Contributors (Commonwealth Scientific and Industrial Research Organization—Publications)	24	..
Science and Industry Endowment Fund	1,991	1,991
Miscellaneous Contributors (Mathematical Instruments Section)	30	..
Wool Scourers, Carbonizers, and Fellmongers Federation of Australia (Wool Textile Research)	3,000	..
Various Contributors (Foundry Sands Investigations — Division of Industrial Chemistry)	28	..
Australian Wine Board — Oenological Research	2,258	2,119J
Department of Territories (Resources Survey—Papua and New Guinea)	1,477	1,454
George Aitken Pastoral Research Trust Rabbit Investigations	2,375	1,375

F. Includes £500 on account of 1950-51 expenditure.
G. Includes £250 on account of 1950-51 expenditure.
H. Includes £1,000 on account of 1950-51 expenditure.
I. Includes £250 on account of 1950-51 expenditure.
J. Includes £274 on account of 1950-51 expenditure.

	Receipts 1951-52 and balances brought forward from 1950-51.	Expenditure 1951-52.
	£	£
Associated Woollen Worsted Textile Manufacturers of Australia (Wool Textile Research)	8,102	..
Revenue Fund — Fleece Analysis Laboratory (Animal Health and Production Investigations)	1,150	..
Revenue Fund—Toxaemic Jaundice Investigations (Animal Health and Production Investigations)	662	200
Revenue Fund—Contagious Pleuropneumonia Investigations (Animal Health and Production Investigations)	3,150	2,554
Revenue Fund—Oestrus Experiment (Animal Health and Production Investigations)	4,841	1,967
Revenue Fund—Sale of Contagious Pleuropneumonia Vaccine (Animal Health and Production Investigations)	10,618	4,130
Revenue Fund — Cobram Field Station (Animal Health and Production Investigations)	4,370	518
Revenue Fund—Burdekin Bequest (Animal Health and Production Investigations)	765	733K
Revenue Fund—Anaplasmosis Investigations (Animal Health and Production Investigations)	96	..
Revenue Fund—Parkville Laboratory (Animal Health and Production Investigations)	764	..
Revenue Fund—Tooradin Field Station (Animal Health and Production Investigations)	1,084	1,000
Revenue Fund—Poultry Breeding Investigations, Werribee (Animal Health and Production Investigations)	9,790	9,531
Revenue Fund — Werribee Farm Mastitis Investigations (Animal Health and Production Investigations)	8,424	4,273
Revenue Fund—Drought Feeding Investigations, Werribee (Animal Health and Production Investigations)	576	..
Revenue Fund — National Field Station, "Gilruth Plains", Cunnamulla, Queensland (Animal Health and Production Investigations)	43,347	24,750
Reserve Fund — National Field Station, "Gilruth Plains", Cunnamulla, Queensland (Animal Health and Production Investigations)	15,481	481
Revenue Fund — Sheep Biology Investigations (Animal Health and Production Investigations)	14	..
Revenue Fund—Bacteriological Investigations (Animal Health and Production Investigations)	16	16L
Revenue Fund—Parasitological Investigations (Animal Health and Production Investigations)	4,749	167
Revenue Fund—Wool Biology Investigations (Animal Health and Production Investigations)	207	..
Revenue Fund—Regional Pastoral Research Station (Animal Health and Production Investigations)	46,540	20,799
General Donations—Building Research Section	153	..
Revenue Fund—Infertility F.D. McMaster Field Station (Animal Health and Production Investigations)	7,482	5,576
Revenue Fund—Veterinary Parasitology Laboratory (Animal Health and Production Investigations)	344	..
Revenue Fund—Toxaemic Jaundice Investigations, Barooga, New South Wales (Animal Health and Production Investigations)	3,494	686

K. Includes £333 on account of 1950-51 expenditure.
L. Includes £16 on account of 1950-51 expenditure.

	Receipts 1951-52 and balances brought forward from 1950-51. £	Expenditure 1951-52. £
Revenue Fund—Nutrition Laboratory (Biochemistry and General Nutrition Investigations)	15,056	2,753
Revenue Fund—Plant Industry Investigations	15,594	3.643M
Revenue Fund—Stanthorpe Field Station (Plant Industry Investigations	4,136	..
Revenue Fund—Glen Lossie Field Station (Plant Industry Investigations)	17,916	2,052
Revenue Fund—Deniliquin Regional Pastoral Laboratory (Plant Industry Investigations)	13,057	531
Revenue Fund—Cooper Laboratory (Plant Industry Investigations)	206	..
Revenue Fund—Tobacco Investigations	82	..
Revenue Fund—Entomological Investigations	1,150	..
Revenue Fund—Griffith Research Station (Citricultural Investigations)	10,054	1,149
Revenue Fund—Merbein Research Station (Viticultural Investigations)	12,726	2,955
Revenue Fund—Division of Food Preservation and Transport	676	280
Revenue Fund—Egg Investigations (Division of Food Preservation and Transport)	168	..
Revenue Fund—Division of Forest Products	1	..
Revenue Fund—Mining and Metallurgy	14	..
Revenue Fund—Ore-dressing Investigations	1,315	..
Revenue Fund—Central Experimental Workshops	14	..
Revenue Fund—Fisheries Investigations	1,175	1,175N
Revenue Fund—Physics	1,892	..
Revenue Fund—Metrology	5,396	..
Revenue Fund—Mathematical Instruments	26	..
Revenue Fund—Dairy Investigations	33	..
Revenue Fund—Electrotechnology	778	..
Revenue Fund—Microanalysis Investigations	1,276	1,276
Revenue Fund—Industrial Chemistry	649	..
Revenue Fund—Radiophysics	127	..
Revenue Fund—Tribophysics	1	..
Revenue Fund—Meteorological Physics	12	..
Revenue Fund—Merbein Research Station Production of Pyrethrum	185	..
Revenue Fund—Wool Textile Research	208	..
Revenue Fund—Wool Wax Report—Royalties (Information Service)	6	..
Revenue Fund—Land Research and Regional Survey	131	..
	685,586	451,155

3. WOOL RESEARCH TRUST ACCOUNT.

A credit balance of £812,223 was brought forward from 1950-51 in the Wool Research Trust Account. A further £340,505 was received during 1951-52 from the Department of Commerce and Agriculture. Expenditure during 1951-52 was as follows:—

	£	£	£
Division of Animal Health and Production—			
Parkville—			
Sheep Physiology Investigations—Parkville	5,532		
Sheep Physiology Investigations—Tooradin	2,198		
Toxaemic Jaundice Investigations—Barooga	765		
Toxaemic Jaundice Investigations—Cobram	1,198		
McMaster Laboratory—			
Parasitology Investigations—New South Wales	6,441		
Parasitology Investigations—Tasmania and Western Australia	1,346		
Parasite Physiology and Toxicology	1,844		
Biochemical Investigations	3,039		
Physiology of Reproduction	1,772		
Dipping and External Parasites	1,089		
Glenfield Research Station—			
Drought Feeding Investigations	2,365		
Veterinary Parasitology Laboratory, Yeerongpilly—			
Animal Physiology Investigations at University of Queensland	1,166		
Sheep Biology Laboratory, Prospect—			
Administrative and General Expenses	4,564		
Fleece Analysis	16,776		
Wool Biology Investigations	14,604		
Strain Trial Investigations	8,550		
Regional Pastoral Laboratory, Armidale—			
Parasitology, Agrostology, and Field Investigations	33,564		
McMaster Field Station—			
Survey of Wool Production	1,587		
National Field Station, Gilruth Plains—			
Capital Expenditure	652		
Animal Breeding and Strain Trial Investigations	3,402		
Agrostology Investigations	554		
		113,008	
Division of Plant Industry—			
Agrostolgy Investigations	47,923		
Mineral Deficiency studies	2,616		
		50,539	
Research Services—			
Agricultural Research and Extension Liaison	2,573		
Review of Wool Programme for Publication	83		
		3,056	
Division of Industrial Chemistry—			
Expenditure on Wool Textile Research—			
Chemical Physics Investigations	8,014		
Organic Chemistry Investigations	9,238		
Physical Chemistry Investigations	1,197		
Clover Infertility Tests, Western Australia	50		
		18,499	
Division of Biochemistry and General Nutrition—Biochemical and Nutritional Investigations	28,115		
		28,115	
Wool Textile Research Laboratories—Wool Textile Research	124,672		
		124,672	
Wildlife Survey Section—Wildlife Survey	9,688		
		9,688	
Animal Genetics Section—Animal Genetics Investigations	4,311		
		4,311	
Miscellaneous—Overseas Studentships	11,037		
		11,037	
			362,925

M. Includes £900 on account of 1950-51 expenditure.
N. Includes £243 on account of 1950-51 expenditure.

	£	£	£
Grants from Wool Research Trust Account to Institutions undertaking extra-mural co-operative wool research—			
University of Adelaide, Waite Institute—Agrostology, Weeds and Entomology Investigations	4,000		
University of Western Australia—Investigations at Institute of Agriculture, Western Australia	3,825		
Department of Agriculture, Western Australia — Sheep Infertility Investigations and Mineral Deficiencies of Pastures	4,054		
Roseworthy Agricultural College—Progeny Testing and Allied Studies	3,624		
Sydney Technical College—Wool Clip Analysis	2,500		
University of Queensland—Sheep Physiology Investigations ..	1,050		
University of Melbourne—Sheep and Wool Survey	200		
University of Sydney—Animal Physiology and Sheep Infertility Investigations ..	2,070		
Report by Dr. A. L. Hagedoorn ..	400		
Gordon Institute of Technology, Geelong—Wool Textile Investigations	2,870		
Wool Industries Research Association, Leeds, United Kingdom—Wool Textile Investigations	1,254		
		25,847	
Grants from Wool Research Trust Account to Institutions undertaking research in Agricultural Economics relating to wool production—			
University of Western Australia	400		
Roseworthy Agricultural College	356		
Department of Commerce and Agriculture, Division of Agricultural Economics ..	23,759		
Market and Consumer Research Limited	1,921		
		26,436	
Grant from Wool Research Trust Account to Wool Realization Commission in connexion with Wool Sales Statistics	5,215		
		5,215	
			57,498
			420,423

4. Wool Industry Fund.

A credit balance of £7,675 was brought forward from 1950-51 in the Wool Industry Fund Account. A further £315,000 was received during 1951-52. Expenditure during 1951-52 amounting to £292,046 was incurred as follows:—

	£	£	£
Division of Animal Health and Production—			
Sheep Biology Laboratory—Prospect—			
Animal house No. 2	77,698		
First cottage	144		
Feed store animal house No. 1	295		
Prefabricated buildings ..	21,876		
Climate rooms and services ..	1,300		
Acquisition of land at Deniliquin for Strain Trials ..	40,000		
Earth tank	2,181		
Developmental expenditure—Fencing, roads, water supply, &c.	1,731		
McMaster Laboratory — Small animal accommodation ..	5,813		
Regional Pastoral Laboratory and Chiswick Field Station, Armidale—			
Annexe No. 1 and No. 2 and Field Laboratory	11,905		
Erection of five cottages ..	14,776		
Construction of small buildings and roads and provision of services at Armidale ..	4,565		
McMaster Field Station—Cottage for sheep overseer	125		
Adjustment of expenditure incorrectly charged to Wool Industry Fund during 1950-51 in connexion with erection of small buildings at Cobram and electrical installations at Glenthorne	*Cr.* 77		
		182,332	
Division of Plant Industry—			
Head-quarters, Agrostology Section, Canberra—Advance payment on erection, fittings, partitions, &c., for Agrostology and Pasture Chemistry prefabrications	2,500		
Regional Pastoral Laboratory and Falkiner Memorial Field Station, Deniliquin—Erection of laboratory	7,440		
Western Australian Investigations—			
Pot Culture Laboratory, Crawley	1,529		
Cottage, Kojonup Field Station	250		
Associated Studies, New South Wales—			
Department of Agriculture, Trangie Field Laboratory	1,411		
Repairs to cottage, Trangie	59		
		13,189	
Wildlife Survey Section—			
Garage and workshop, Albury ..	942		
Refund from Department of Interior in connexion with acquisition of land at Albury	*Cr.* 754		
		188	
Wool Textile Research—			
Melbourne—Biochemistry Unit—			
Conversion of "Quamby" ..	18,006		
Prefabricated building ..	4,745		
Sydney—			
Purchase of "The Hermitage"	14,517		
Conversion of "The Hermitage" to laboratories	2,108		
Erection of storeroom, workshop, and special purpose huts	2,889		
Geelong—			
Factory-type building and staff houses	27,208		
Erection of Sidney Williams hut	1,895		
Fixed plant, including textile machinery	5,023		
		76,391	
Division of Industrial Chemistry—			
Biochemistry laboratory, Fishermen's Bend	14,084		
		14,084	
Grants from Wool Industry Fund in connexion with extra-mural co-operative wool research—			
University of Queensland—Sheep Physiology Investigations ..	1,400		
University of Sydney—Animal Physiology Investigations ..	993		
Walter and Eliza Hall Institute — Myxomatosis Investigations	3,000		
Wildlife Survey Section—Rabbit Investigations	469		
		5,862	
			292,046

5. WORKS PROJECTS (UNDER CONTROL OF C.S.I.R.O.).

Expenditure on works projects from funds made available directly to C.S.I.R.O by the Treasury is as follows:—

	£	£
Homebush Laboratory	2,744	
		2,744

6. MISCELLANEOUS SERVICES.

	£
Contribution to Commonwealth Agricultural Bureaux	20,358
Grant to Standards Association of Australia ..	48,000
Grant to Australian National Research Council ..	3,000
Contribution to Chair of Aeronautics at University of Sydney (establishment and maintenance) ..	5,000
Grant to National Association of Testing Authorities	6,000
International Institute of Radio Science	654
	83,012

XXXVI. ACKNOWLEDGMENTS.

In various sections of this Report reference has been made as in previous years to the valuable assistance afforded by many State Departments, Universities, and other organizations and individuals. The Organization desires to express its gratitude for the help given by these bodies and persons in providing laboratory accommodation and other facilities and in many other ways. The Organization also wishes to acknowledge the assistance it has received from its Committees, the members of which have placed their knowledge and experience so freely at its disposal.

I. CLUNIES ROSS, Chairman
F. W. G. WHITE
A. B. RITCHIE
H. J. GOODES
S. H. BASTOW
Executive.

30th October, 1952.

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